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TEXTILE RESEARCH JOURNAL

VOL. XVI, No. 10 October, 1946

Air Permeability of Fabrics

L. W. Rainard

Institute of Textile Technology, Charlottesville, Virginia

Introduction

The permeability of fabrics to air and other gases which are not absorbed to a large extent by fibers is of considerable practical and theoretical interest. Heretofore there has been no general recognition of the importance of air permeability of porous fabrics at very low velocities, although Marsh [1] and Sale and Hedrick [2] emphasize that heat losses may occur by convection currents which would operate at low-pressure differentials. Similarly, there are many drying problems closely associated with water-vapor permeability and air permeability at low velocities.

The recent review by Sieminski and Hotte [3] indicates that no adequate technique for measuring the air permeability of relatively open fabrics has been developed nor has any general expression been evolved which describes the properties of a fabric over a wide range of air velocities. In fact most of the previous work has been concerned with techniques rather than with the general principles of permeability. This work was undertaken in an attempt to devise a method for obtaining significant data on the low-velocity permeability of fabrics and to consider the general description of a fabric in terms of air permeability over a wide range of velocities of air.

Experimental Data

For the purpose of these experiments a standard Frazier machine designed by Schiefer and Boyland [4] was used, as well as an apparatus designed especially for determining permeability at very low pressure. The Frazier machine was calibrated at the factory. Each fabric was tested in at least 3 spots and most of the samples were tested in 4 to 6 spots. For each spot the amount of air passed through the fabric was determined as a function of pressure differential. The data were then averaged and plotted. The plots of the data were generally weighted in favor of the higher pressure differentials, because at low pressures the percentage of error is greatest. Otherwise there was no special handling of the fabrics in the Frazier permeability tests.

For the low-pressure work an apparatus was used which consisted essentially of a very sensitive manometer and a wet-test, gas-volume meter (Figure 1). The air was supplied from a compressed-air line; the air pressure was roughly controlled by a tank and float arrangement and further controlled with a needle valve. Since the air leaving the pressure-control tank was saturated with water, it was passed through a trap set in an ice-salt mixture to freeze out the water and then to a heated trap to bring the air up to room temperature. From the heated trap the air was led to a fabric holder (detailed in Figure 2) and thence to the wet-test meter. The manometer was a glass tube 30 inches long with a 1-millimeter bore. The tube and reservoir were filled with hexane colored with sudan red. The incline of the tube was adjusted from a carefully leveled bar by means of plumb bobs suspended from the bar. The measurements of pressure were made with inclinations running from 0.25-inch to 0.5-inch rise per 30 inches of tube. The measurements with this apparatus were made in order to supply a check with

a different type of instrument as well as to obtain some low-velocity data.

Figures 3–17 and Tables I–XV give air flows at their corresponding pressure differentials and the ratios of flow to pressure for each of the fabrics tested. The terminology used throughout gives Δp as pressure differential in inches of water and F_a as air volume in cubic feet per minute per square foot of fabric at ASTM Standard conditions.

Because the data obtained for the white piqué both with the Frazier permeability tests and the experimental apparatus used here were exceptionally uniform, average values obtained from the Frazier tests were plotted along with the data from Table XII.

Examination of the curves of Figures 13, 15, 16, and 17 will show that the intercepts of the $(F_a/\Delta p)$–Δp curves when Δp is zero only approximate the average values obtained from the Frazier permeability tests. However, if the $(F_a/\Delta p)$–Δp curves obtained from the Frazier tests are plotted individually, not as average values, it can be seen that the individual curves are straight lines, essentially parallel, with various intercepts (Figure 18).

Discussion

The curves of $(F_a/\Delta p)$ versus Δp appear to be straight lines, within experimental errors. It is therefore possible to extrapolate this type of curve to $\Delta p = 0$ and obtain what might be called an intrinsic permeability, P_i.

This concept of intrinsic gas permeability is valuable when considering fabrics of normal construction in relation to air moving at low velocities. The flow of air through a fabric would ordinarily be proportional to the pressure if the flow were streamlined and steady. Thus, according to Poiseuille's law,

$$F_a = \Delta p K \tag{1}$$

where K is a constant which includes factors for converting to English units, as well as the factor

$$\frac{n\pi R^4}{8\eta l},$$

where R is the radius and l the length of each of the n capillaries and η is the viscosity of air. Thus, the curves of $F_a/\Delta p$ vs. Δp should be straight lines with zero slope. From a consideration of the preceding section, it can be seen that the slopes of these curves vary. The inference is that the slope of the line represents a summation of all the fabric characteristics and the air flow characteristics which prevent adherence to the Poiseuille's law of flow. With the onset of turbulent flow, Reynolds' equation applies:

$$F_a = (\Delta p)^n K'. \tag{2}$$

However, under conditions of steady flow, the deviation from Poiseuille's law is due to the compressibility of air and the kinetic energy of the gas moving through the fabric.

Since we have assumed a straight-line function in the variation of $F_a/\Delta p$ with Δp, it can be seen that the permeability of a fabric can be calculated for other pressures from the intrinsic permeability and the slope of the $(F_a/\Delta p)$–Δp curve.

If we define the slope as

$$K = \frac{\dfrac{F_{a0}}{\Delta p_0} - \left(\dfrac{F_a}{\Delta p}\right)_{\Delta p=0}}{\Delta p_0}, \tag{3}$$

$$K = \frac{\dfrac{F_{a0}}{\Delta p_0} - P_i}{\Delta p_0}, \tag{4}$$

where Δp_o is any chosen arbitrary pressure whose corresponding air flow (F_{ao}) is known, then K will

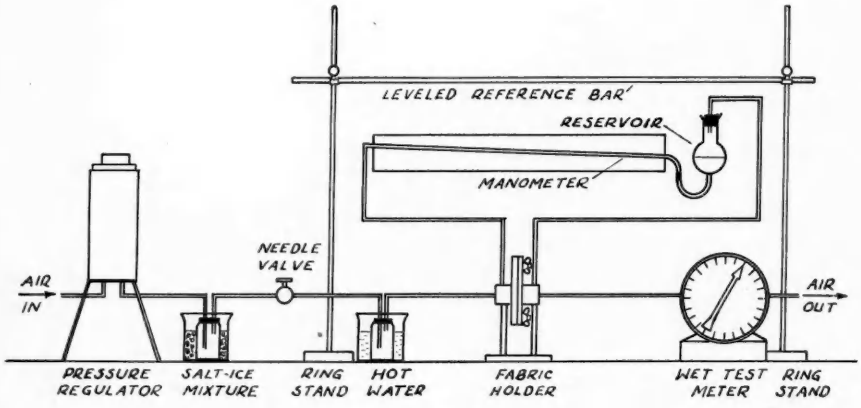

FIG. 1. *Apparatus for testing air permeability of fabrics at low pressure.*

represent the slope of the straight line whose equation takes the following form:

$$\frac{F_a}{\Delta p} = K\Delta p + P_i. \tag{5}$$

Solving for F_a gives:

$$F_a = K\Delta p^2 + P_i\Delta p. \tag{6}$$

The air permeability of a fabric, then, is described by an empirical equation, where the two constants of the fabric must be known—K, the slope of the $F_a/\Delta p$ vs. Δp curve, and P_i, the intercept at $\Delta p = 0$. It will be observed that equation (6) gives a flow of air which is not a linear function of pressure differential. An examination of the F_a vs. Δp curve reveals that there is a slight curvature in the range of pressures measured. This equation can apply only over a certain range, because K always has a negative value and because the square of the pressure differential appears in the first term. At large values of Δp the first term would be negative and larger than the second term, resulting in meaningless values of F_a. If, however, we differentiate equation (6),

$$F_a = K\Delta p^2 + P_i\Delta p, \tag{6}$$

$$\frac{d(F_a)}{d(\Delta p)} = 2K\Delta p + P_i, \tag{7}$$

and set equation (7) equal to zero,

$$2K\Delta p + P_i = 0. \tag{8}$$

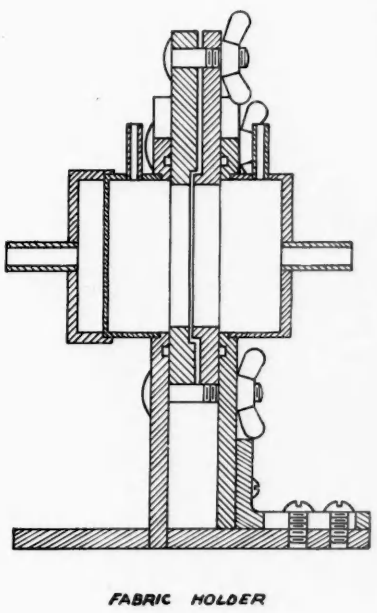

FIG. 2. *Fabric holder.*

Solving for Δp,

$$\Delta p = \frac{-P_i}{2K}, \tag{9}$$

we obtain the theoretical pressure differential beyond which this equation does not apply.

The intrinsic permeability seems to be related to the amount of voids in the fabric and the slope K is probably related to various structural elements.

Equation (6) can be written in a more convenient form for the purposes of calculating air flow as a function of pressure differential in terms of any known air flow, in corresponding pressure, differential, and intrinsic permeability. By combining equations (4) and (6) the following equation is obtained:

$$F_a = \left(\frac{\frac{F_{a0}}{\Delta p_0} - P_i}{\Delta p_0}\right)\Delta p^2 + P_i\Delta p, \tag{10}$$

where F_{ao} is the air flow at any pressure differential Δp_0.

The standard ASTM permeability test is limited in the amount of information it gives. Fabrics 5 and 6 in Table XVI have approximately the same permeabilities at 0.4 inch of water, yet they are quite different at low air velocities, as indicated by their P_i values. A more adequate description of the air permeability of fabric can be obtained by determining the P_i and K values of the particular fabric.

Fabrics with carefully controlled variations in their structures are being produced, and this work will be extended in an attempt to find some correlation between structure and the constants described here. Studies are to be continued in the high-pressure regions.

Summary

1. Two new factors, namely, the "intrinsic permeability" and the slope $(F_a/\Delta p)$–Δp curve, are described which may have some general utility in defining a fabric with respect to air permeability.

2. A method is suggested for deriving some properties of fabrics with respect to air passage at low air velocities.

3. An equation is presented whereby the rate of air flow through a fabric at any given pressure can be calculated.

4. A basis is suggested for future work correlating structural changes in fabrics with air permeability characteristics.

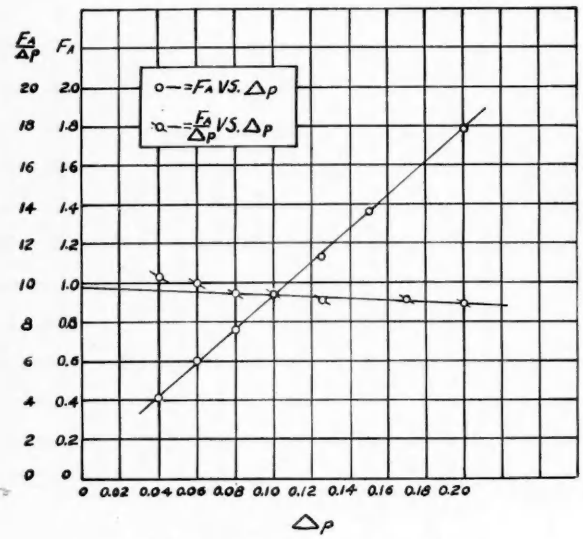

FIG. 3. *Plot of the data of Table I.*

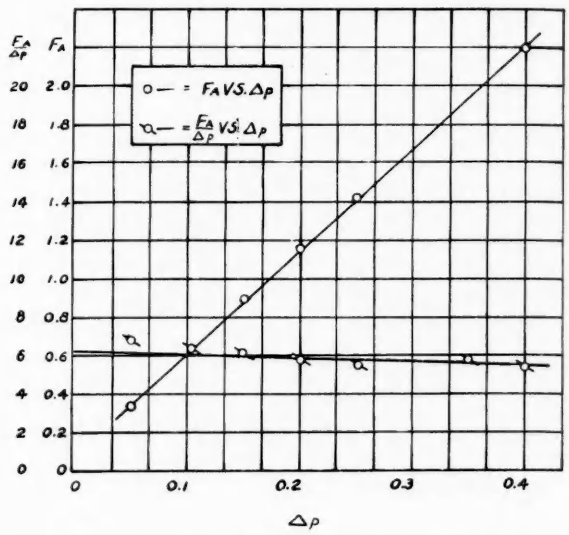

FIG. 4. *Plot of the data of Table II.*

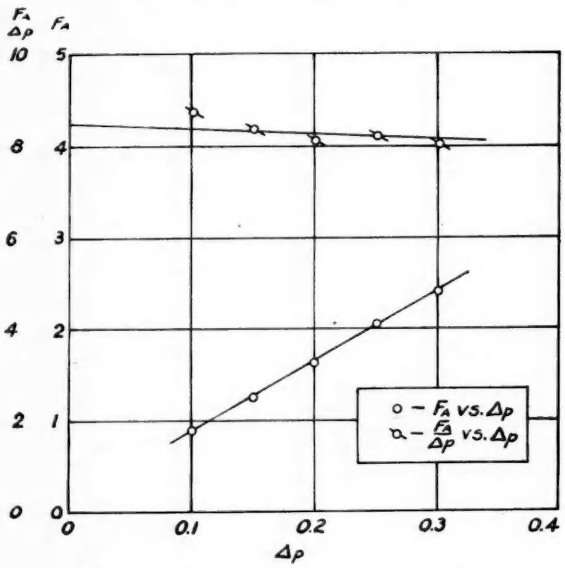

FIG. 5. *Plot of the data of Table III.*

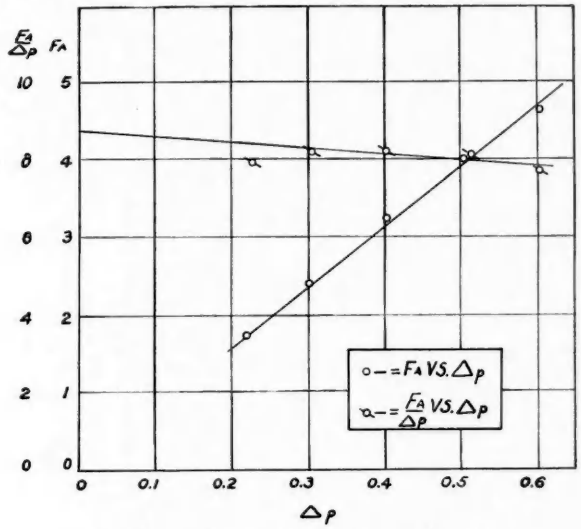

FIG. 7. *Plot of the data of Table V.*

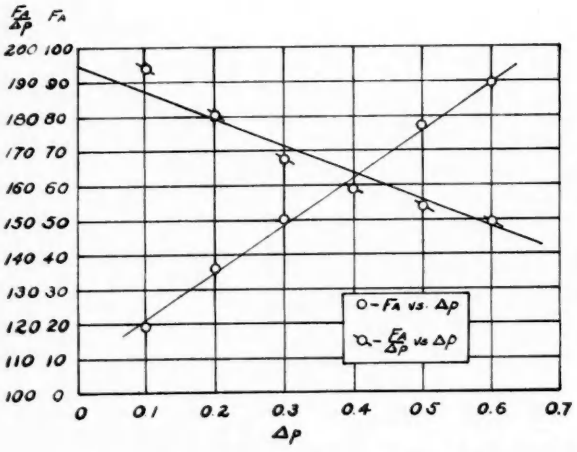

FIG. 6. *Plot of the data of Table IV.*

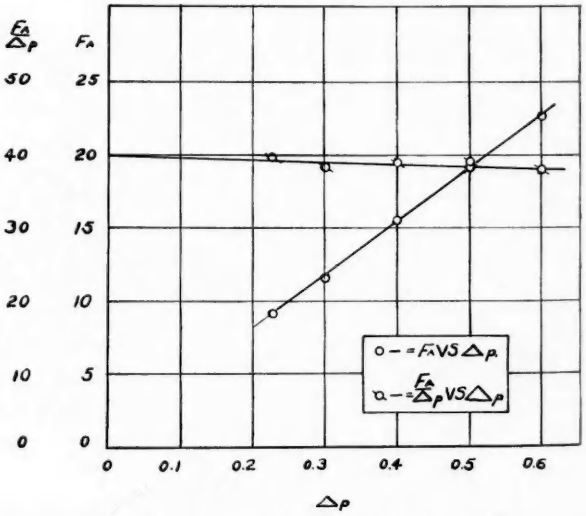

FIG. 8. *Plot of the data of Table VI.*

TABLE I. Frazier Tester. U. S. Army Sateen; Approximately 6-Ounce Cotton, Dyed, Unfinished; Fairly Closely Woven Fabric (Figure 3)

Orifice No. 1 4 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.200	1.79	8.95
0.150	1.36	9.08
0.125	1.13	9.05
0.100	0.94	9.40
0.080	0.76	9.51
0.060	0.60	10.00
0.040	0.41	10.30

TABLE II. Frazier Tester. U. S. Army Tent Twill; 11.6-Ounce Gray, Desized, Cotton; Heavy, Closely Woven Fabric (Figure 4)

Orifice No. 1 6 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.40	2.2	5.5
0.35	2.06	5.8
0.25	1.41	5.63
0.20	1.16	5.80
0.15	0.90	6.0
0.10	0.64	6.4
0.05	0.34	6.8

TABLE III. Frazier Tester. U. S. Army Duck; 12.1-Ounce Gray, Desized Cotton, General-Purpose Duck (Figure 5)

Orifice No. 1 5 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.30	2.41	8.05
0.25	2.05	8.20
0.20	1.62	8.10
0.15	1.25	8.35
0.10	0.89	8.90

TABLE IV. Frazier Tester. White Piqué 176 × 116; 3.5-Ounce Cotton, Light Fabric, Characterized by Alternating Dense and Open Stripes (Figure 6)

Orifice No. 6 3 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.6	89.5	149
0.5	77.1	154
0.4	63.5	159
0.3	50.5	168
0.2	36.3	181
0.1	19.4	194

TABLE V. Frazier Tester. U. S. Army Field-Jacket Cloth; Zelan-Finished, 5.1-Ounce Cotton; Closely Woven, Very High Count, Light Twill (Figure 7)

Orifice No. 2 4 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.6	4.65	7.75
0.5	4.00	8.0
0.4	3.25	8.13
0.3	2.41	8.1
0.22	1.76	7.9

TABLE VI. Frazier Tester. U. S. Navy Blue Denim No. 27 NR Sanforized Regulation Denim (Figure 8)

Orifice No. 4 4 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.6	22.5	37.5
0.5	18.9	37.8
0.4	15.3	38.3
0.3	11.4	38.0
0.23	9.0	39.1

TABLE VII. Frazier Tester. Cotton Sheeting; Finished "Duracale," Marshall Field and Company (Figures 9 and 18)

Orifice No. 4 4 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.8	20.8	26.0
0.7	19.2	27.4
0.6	16.5	27.5
0.5	13.8	27.6
0.4	11.2	28.0

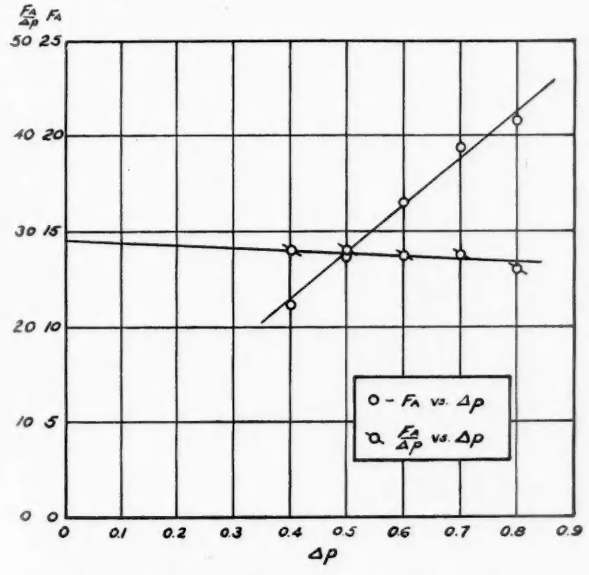

Fig. 9. *Plot of the data of Table VII.*

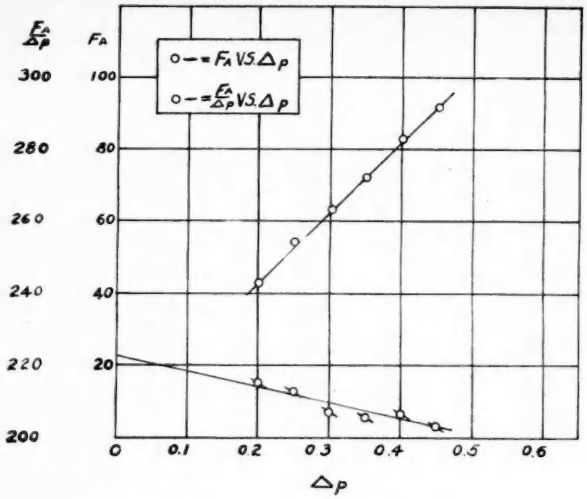

FIG. 10. *Plot of the data of Table VIII.*

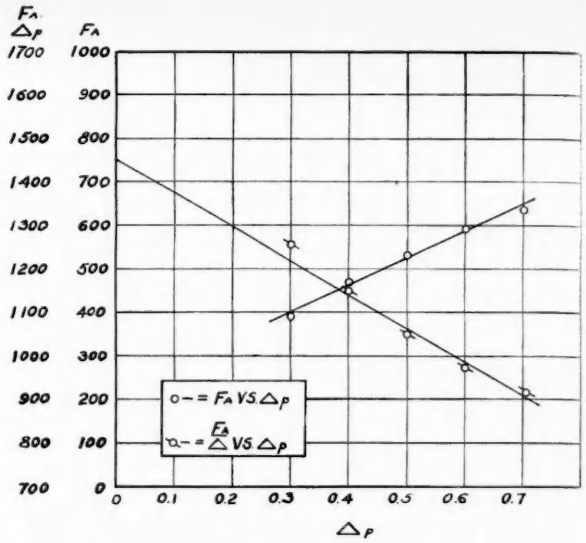

FIG. 11. *Plot of the data of Table IX.*

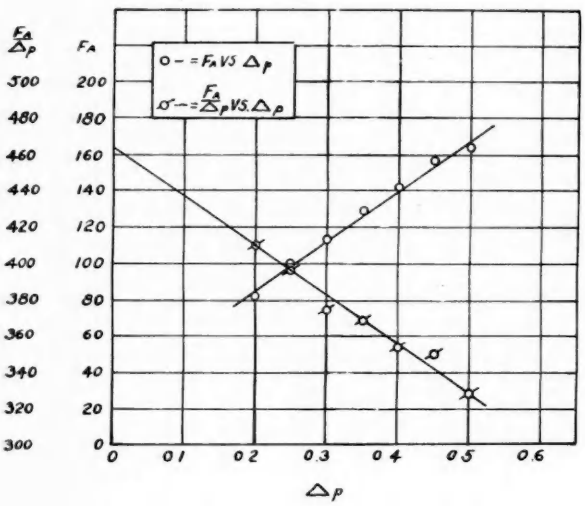

FIG. 12. *Plot of the data of Table X.*

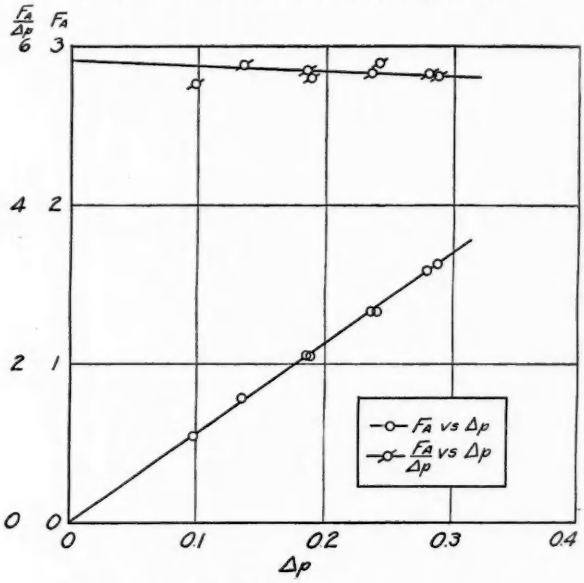

FIG. 13. *Plot of the data of Table XI.*

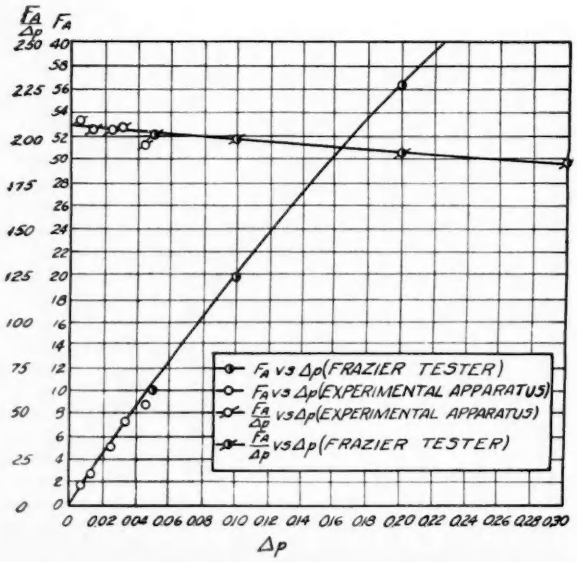

FIG. 14. *Plot of the data of Table XII.*

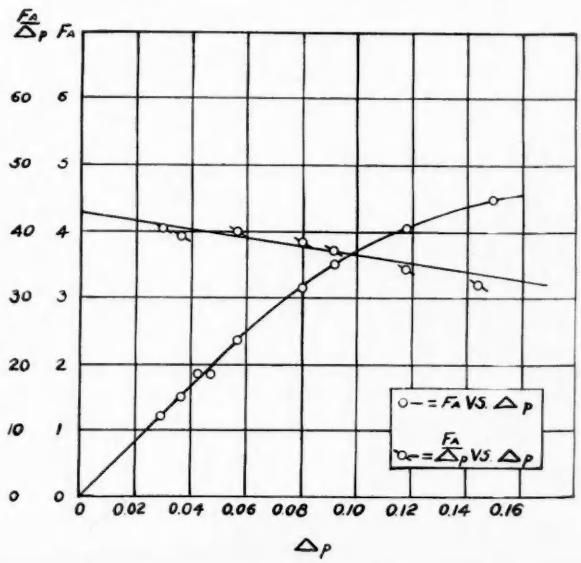

FIG. 15. *Plot of the data of Table XIII.*

TABLE VIII. Frazier Tester. 12-Ounce Wool Suiting, Softly Woven Fabric of Uniform Construction (Figure 10)

Orifice No. 6 4 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.45	91.5	203
0.40	82.1	206
0.35	71.9	206
0.30	62.2	207
0.25	53.1	212
0.20	43.0	215

TABLE X. Frazier Tester. Cotton Damask, 74 × 78, 1.65 Yards per Pound, Light-Weight, Characterized by a Wide Distribution in Size of Openings (Figure 12)

Orifice No. 7 3 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.5	164	328
0.45	157	350
0.40	141	353
0.35	129	369
0.30	112	374
0.25	99	396
0.20	82	410

TABLE XII. Experimental Apparatus: Manometer Set at 0.25-Inch Rise for 30 Inches of Tube. White Piqué, Same as Used in Table IV (Figure 14)

Δp	F_a	$\frac{F_a}{\Delta p}$
0.0455	8.69	191
0.0341	7.15	210
0.0237	4.94	208
0.0120	2.50	208
0.00863	1.87	217

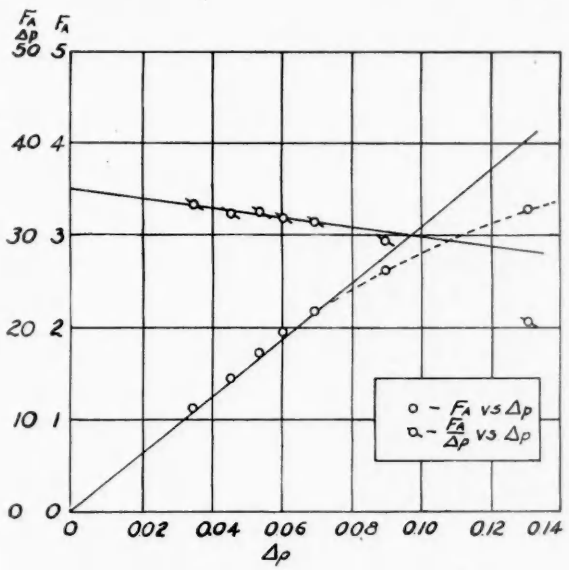

Fig. 16. *Plot of the data of Table XIV.*

TABLE IX. Frazier Tester. Rayon, Plain Weave, 50 × 36, 3.3-Ounce, Very Open (Figure 11)

Orifice No. 9 4 spots tested

Δp	F_a	$\frac{F_a}{\Delta p}$
0.7	638	913
0.6	588	980
0.5	525	1,050
0.4	461	1,150
0.3	380	1,270

TABLE XI. Experimental Apparatus: Manometer Set at 0.5-Inch Rise for 30 Inches of Tube. U. S. Army Field-Jacket Cloth; Zelan-Finished, 5.1-Ounce Cotton, Same as Used in Table V (Figure 13)

Δp	F_a	$\frac{F_a}{\Delta p}$
0.280	1.58	5.66
0.289	1.63	5.64
0.241	1.345	5.81
0.237	1.345	5.67
0.188	1.056	5.63
0.185	1.056	5.71
0.135	0.777	5.74

TABLE XIII. Experimental Apparatus: Manometer Set at 0.25-Inch Rise for 30 Inches of Tube. Navy Denim, Same as Used in Table VI (Figure 15)

Δp	F_a	$\frac{F_a}{\Delta p}$
0.1442	4.51	31.2
0.1439	4.49	31.2
0.1173	4.04	34.4
0.0919	3.43	37.4
0.0800	3.07	38.4
0.0571	2.30	40.3
0.0475	1.83	38.6
0.0470	1.84	39.1
0.0365	1.45	39.7
0.0289	1.16	40.2

TABLE XIV. Experimental Apparatus: Manometer Set at 0.25-Inch Rise for 30 Inches of Tube. Finished "Duracale" Sheeting, Same as Used in Table VII (Figure 16)

Δp	F_a	$\frac{F_a}{\Delta p}$
0.1305	3.27	25.05
0.1301	3.24	24.9
0.0902	2.62	29.1
0.0897	2.62	29.2
0.0704	2.18	31.0
0.0698	2.17	31.1
0.0694	2.17	31.3
0.0602	1.95	32.3
0.0536	1.72	32.1
0.0533	1.73	32.4
0.0454	1.44	31.6
0.0450	1.45	32.1
0.0342	1.14	33.3

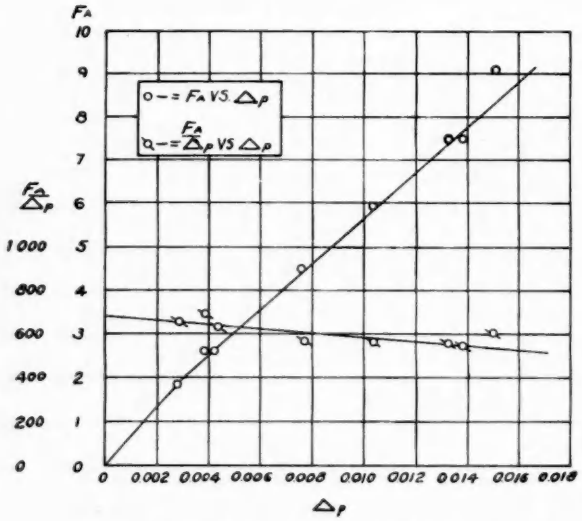

FIG. 17. *Plot of the data of Table XV.*

TABLE XV. EXPERIMENTAL APPARATUS: MANOMETER SET AT 0.25-INCH RISE FOR 30 INCHES OF TUBE. COTTON DAMASK, SAME AS USED IN TABLE X (FIGURE 17)

Δp	F_a	$\frac{F_a}{\Delta p}$
0.0151	9.04	600
0.0137	7.47	545
0.0132	7.43	563
0.0103	5.93	575
0.0078	4.46	574
0.0042	2.68	635
0.0039	2.68	689
0.0029	1.96	668

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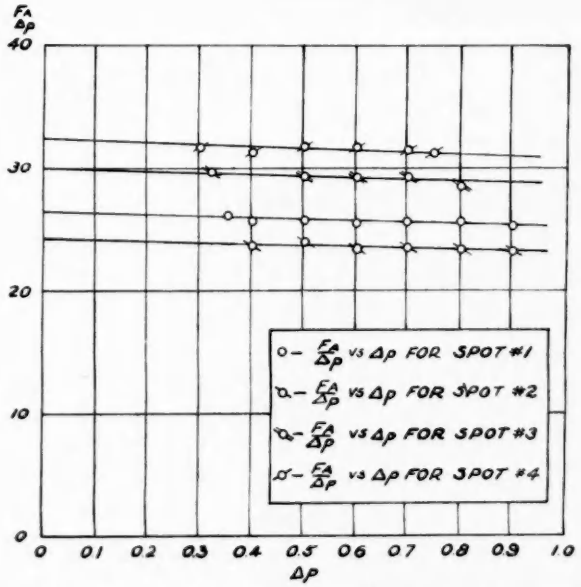

FIG. 18. *Plot of* F_a/Δ *against* Δp *for each of the spots tested with the cotton sheeting used in Table VII.*

TABLE XVI. INTRINSIC PERMEABILITIES, SLOPES, AND ASTM PERMEABILITIES OF THE FABRICS AT 0.4 INCH OF WATER

	P_i	K	ASTM permeability
1. Army sateen	9.7	– 4.67	—
2. Duck (gray)	8.5	– 1.33	—
3. Tent twill (gray)	6.3	– 2.0	2.2
4. Field-jacket cloth	8.7	– 1.67	3.5
5. Sheeting	29.5	– 3.33	14.0
6. Navy blue denim	40.0	– 4.17	15.5
7. White piqué	195.0	– 78.4	62.5
8. Wool suiting	222.5	– 43.3	83.0
9. Cotton damask	465.0	–274	141
10. Rayon light weave	1460.0	–722	465

(The ASTM value was given at 0.4 inch of water to include as many of the fabrics as possible.)

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Some Notes on Cellulose Solvents and Their Application to Special Textile Finishes*

C. L. Mantell†

THE subject of cellulose solvents has been of interest to a large number of scientific workers for many decades. All of us are familiar with the work of Chardonnet in France, Cross and Bevan in England, and a number of similar groups in other countries. The conversion of purified cellulose into sodiocellulose by treatment with caustic and the reaction of this sodiocellulose with carbon bisulfide to form xanthates are given in our elementary chemistries as the basic reactions for viscose rayon. The solubility of purified celluloses in copper-ammonium complexes, often referred to as Schweitzer's reagent, is given in the same books as being basic for the preparation of cuprammonium rayon, perhaps better known by its trade name of Bemberg.

It is to be remembered that xanthates may be subjected to chemical reactions commonly by acids so that cellulose is precipitated in a regenerated form. If a xanthate solution is applied to a fabric by dipping or coating or other mechanical means and the fabric is treated with a precipitating agent, deposits of regenerated cellulose will be formed and, depending upon the conditions, affixed to the fibers of the fabric. A number of patents deal with modifications of this basic reaction as a mechanism for finishing of the fabric or imparting characteristics as a function of precipitated or regenerated cellulose on the fabric. Many of these proposed finishing treatments have achieved little commercial utilization since xanthate solutions are of high viscosity, which makes them somewhat difficult to work or apply, or they may need to be aged to acquire stability of composition or of viscosity, or the raw materials therefor must be very closely controlled to achieve uniformity, or the application of the solutions on conventional finishing equipment introduces some corrosion or mechanical difficulties.

By far the major application of the cellulose xanthates has been in the preparation of cellophane and its related products or filament and spun rayon of the viscose variety. It is to be borne in mind that the fabrics are made of filament and spun rayon viscose, and that these in turn are subjected to textile-finishing processes. The finishing processes have as their object the addition of characteristics which are lacking in the products of the loom or their scoured, cleansed, dyed, printed, or decorated successors.

It is perhaps stretching the concept of solubility of cellulose in a solvent to too great a degree to consider viscose in this connection. Closer to the subject, however, is the solubility of purified forms of cellulose in the copper-ammonium solutions of the Schweitzer's reagent type. It will be recognized that it is possible to have a solution of cellulose in cuprammonium compounds and immerse fabrics therein and subject the treated cloth to reagents which will precipitate the cellulose. Ordinarily from the viewpoint of the textile finisher such processes are susceptible to closer control and duplication than are corresponding ones based on viscose. There is, however, the disadvantage that copper is liable to be plated out on iron portions of the machinery and that the copper-ammonium solutions introduce corrosion difficulties and require specialization of materials of construction and modification of certain machine parts, particularly those made of copper and its alloys. However, finishes have been produced in specialized plants with specialized equipment, taking advantage of the solubility action of the Schweitzer variety of copper-ammonium solutions. Their use has not been extensive.

Chemical modification of cellulose so that hydroxyethyl celluloses are produced allows the preparation of solutions of these primarily in caustic, of varying

* The processes described in this paper are the subject of patent applications.

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viscosities and concentrations so that they may be applied as textile finishing materials. The cellulose compounds are commonly precipitated by hot water or acids which neutralize the caustic solvent. The precipitated hydroxyethyl cellulose may serve as a carrier for fillers such as clays or coloring matters such as insoluble pigments. Application of this type of procedure has been wide in connection with some form of dimensional stability, filling, the addition of weight, the increase of stiffness, or varying surface characteristics.

Another variant is the use of cellulose ethers, particularly those of the water-soluble type such as methyl cellulose. Formerly this was not competitive, in that methyl cellulose was higher priced, but increasing production has brought lower prices and greater utilization of methyl cellulose. It is to be borne in mind, however, that in these cases of the hydroxy alkyl and the alkyl ethers of cellulose the cellulose has been subjected in advance to chemical manufacturing processes and is hardly pure cellulose any longer.

Another variant involves the use of specially purified forms of cellulose and its solution in sodium zincate. Solubility can be achieved at temperatures below 5°C with production of fairly viscous solutions. Ageing and stabilization are ordinarily desirable and usually required.

These solutions are and have been applied as finishing agents, the cellulose being precipitated on the fabric by acids commonly and to a lesser extent by hot water or bicarbonates. The solutions may serve as carrying and affixing agents of fillers such as talcs and clays, or of colored pigments. Many millions of yards of military fabrics, particularly those of mosquito-bar netting, were made with this type of treatment.

At this point it is interesting to note that both the hydroxyethyl-cellulose and the sodium-zincate procedures involve the use of strongly alkaline materials. With the common construction materials in textile-finishing plants, sufficient resistance to the action of alkalies is ordinarily had. The processes are therefore reasonably adaptable to existing plants. One, however, has the disadvantage of necessitating a previously manufactured or treated cellulose chemical compound, while the other requires refrigeration or other means of cooling to obtain effective solution below 5°C.

In the case of many fabrics which are made of staples like cotton and rayon, small projecting ends or tendrils or fibers stand up or extend from the fabric. The term "staple" is here used in contrast to "filament," referring either to the cotton from the plant or the cut variety of rayon designated as staple. In thin fabrics the fuzz or extruding fine fibers may interfere with the clarity of the cloth. Clearer cloths may perhaps be produced by more expensive manufacturing procedures. However, there has been considerable development of finishing processes involving sulfuric acids of exacting concentrations or of combinations of mineral acids, the processes having been given the name from the patentees of the Heberlein method. It is apparent that such processes would involve the destruction of ordinary textile equipment if they were applied therein, and therefore necessitate machines made of lead and its alloys or other materials of construction resistant to sulfuric acid. In addition, these processes act fairly rapidly and if not precisely controlled may entirely destroy the fabrics which they are employed to treat. The finishing effects, therefore, of the Heberlein types of processes may be achieved only in plants especially constructed for the operation.

We have found that the solvency power of sodium zincate solutions is markedly improved by the addition of specific amounts of urea or related materials. Sodium zincate solutions alone have a restricted field of application, exhibiting solvency power for but a limited number of cellulose materials and being ineffective for others. This condition holds below 5°C, which is the required maximum temperature at which sodium zincate exerts solvency power on cellulose. As the cellulosic content of sodium zincate solutions increases, the viscosities become enormous. Some relief may be achieved by the use of excessive amounts of sodium zincate but at the cost of introduction of other difficulties.

In the case of the sodium zincate-urea solvents, it is particularly noticeable that an increased number and variety of forms of regenerated cellulose may be treated. These embrace a wide variety of mill and factory wastes which can be put in solution at room temperatures or above without the necessity of cooling or exact temperature control.

The solvent is commonly prepared by mixing together either an alkaline aqueous solution of sodium zincate and urea or by the addition of urea and zinc oxide to an aqueous solution of sodium hydroxide. Potassium compounds may be used, although ordinarily on an economic basis those of sodium are preferred. It is interesting to note that composition

ranges are reasonably limited and have been determined as a result of considerable work. The amount of urea is effective from about 4 to 10 percent by weight and preferably from 6 to 10 percent on the weight of the solution. Below this composition range the solvency power of the solvent is decreased, while little worth-while improvement results at urea concentrations above 10 percent. The zinc oxide percentages are from a minimum of 2 to the saturation value, while the caustic varies from 7 to 15 percent. Solvency power is affected by going below the minimum concentration of the zinc oxide and caustic, while above the maximum little advantage is gained and some difficulties might be experienced. A typical effective solvent, for example, is one composed of 4.5 percent zinc oxide, 10 percent caustic, 10 percent urea, and the balance water. Chemical materials such as cyanamid, guanidine, and guanylurea, for example, which hydrolyze with alkalies or zincates to form urea, may be employed in amounts equivalent to the urea.

Solvency determinations have been made on a wide variety of regenerated cellulose fabrics and compositions, such as yarns, threads, cloth, clippings, card waste, comber waste, lacings, strings, tire cord, or other waste of regenerated cellulose made by viscose, Bemberg, or analogous processes. It is interesting to note the effect of urea on a solution containing 5 grams of regenerated cellulose, 3 grams of zinc oxide, and 12 grams of caustic per 100 cc. This solution was made up at a temperature below 5°C and then allowed to reach room temperature. The original solution had a viscosity of 110 seconds for 100 revolutions using a 500-gram load on a Stormer viscometer at 68°F. The urea additions and their effect on the viscosity are tabulated below.

Grams urea per 100 cc.	Viscosity (seconds)
1	102
2	92
3	81
4	70
5	60
6	52
7	47
8	42
9	38
10	34
11	33
12	32
13	31
14	30
15	30
No urea	110

The effect of urea on the solubility of regenerated cellulose is perhaps dramatically illustrated by the following test. Rayon yarns having a breaking strength of about 10 pounds were suspended from a stopper with a small weight in a test tube of 15-milliliter capacity containing 10 milliliters of a solution of 10 percent caustic soda and 4.5 percent zinc oxide. In this solution the rayon yarn finally ruptures as a result of swelling and solvent action in 8 to 10 hours. In a similar test set up in the same way in a solution containing 10 percent caustic soda, 4.5 percent zinc oxide, and 10 percent urea, the rayon yarn breaks after 10 seconds and passes into solution. Similar tests with hydrazine, phenyl hydrazine, formamide, acetamide, ethylene diamine, phenylethanol amine, propylene diamine, ethylphenyl ethanol amine, phenyldiethanolamine, tri-isopropylamine, triethyl tetramine, pyridine, morpholine, resorcinol, melamine, hexamethylene tetramine, tetraethanol ammonium hydroxide, or tris(hydroxymethyl)amino methane did not reduce the 8-to-10-hour period of the caustic soda-zinc oxide test. In other words, they did not markedly affect the small solvency power of sodium zincate at room temperatures.

From the previous tests it is apparent that the solubility of cellulose in the sodium zincate-urea solutions is effective above 5°C and at room temperature. In contrast to the sodium zincate solvent, no refrigeration is required nor is ripening or ageing necessary to reduce viscosity. The solutions exhibit good viscosity characteristics at various concentrations of solute, as shown by the following table. The sodium zincate solutions were made at temperatures below 5°C.

Concentration of cellulosic material (percent by weight)	Viscosity in poises	
	Present solvent	Sodium zincate
1	(Very thin)	(Very thin)
3	0.50	0.85
4	0.65	1.65
5	63.00	Gelatinous

It might appear that amphoteric metals forming hydroxides and salts or ammonia complexes might be employed in place of zinc oxide. Experimental work over a wide range with copper, nickel, and cobalt oxides and hydroxides showed that their solubility in caustic and urea combinations was low and compounds were not formed which showed cellulose solvency at room temperatures. In the case of the amphoteric metals such as aluminum and tin, aluminates offered little encouragement but stannates with

urea gave useful effects. Solutions of 8 to 15 percent caustic and 1 to 5 percent of sodium stannate were found to have low temperature solubility on rayon waste. In our experiments a minimum of 10 percent of caustic was necessary with 2 to 3 grams of stannate per 100 cc. of solvent. Clear solutions were obtained up to 5 percent regenerated cellulose content after a few minutes of constant stirring. However, after approximately 15 minutes the solution gelled and within an hour was converted to a stiff clear gel. The addition of urea reduced the through a sodium zincate-urea solution and allowed solvent were added, to approximately 20 percent of the viscosity of the solution with no urea. The effect of such a viscosity change is tabulated below for solutions containing 10 grams of caustic soda, 3 grams of sodium stannate, and 1 to 15 grams of urea per 100 cc. of solvent in which 3 grams of rayon waste were dissolved.

Urea (grams per 100 cc.)	Viscosity	
	Seconds	Poises
0	80	15.04
1	71	13.35
2	62	11.65
3	53	9.96
4	42	7.90
5	33	6.20
6	27	5.07
7	22	4.13
8	19	3.57
9	17	3.20
10	16	3.00
11	16	3.00
12	16	3.00
13	15	2.82
14	15	2.82
15	15	2.82

It is interesting to see the solvent effect on regenerated rayon with sodium stannate-caustic solutions with and without urea. In the preparation of 1 gram of rayon waste per 100 cc. in a solvent containing 10 grams of caustic and 4 grams of sodium stannate in 100 cc., the rayon waste requires at least 24 hours to swell and disperse. In a solvent made up of 4 grams of sodium stannate, 10 grams of caustic, and 10 grams of urea per 100 cc., 1 gram of rayon waste dissolves in 10 to 15 minutes. Similar proportions are obtained for higher concentrations of cellulose.

Triangular coordinate diagrams of urea, zinc oxide, and caustic in one series, and of urea, tin oxide, and caustic in another series, have been developed showing the composition areas for solubility of regenerated cellulose of various types and of cotton cellulose, with corresponding values for viscosities, mobilities, stabilities, and gelling tendencies. The data, however, provide a potential foundation for the recovery of wastes incidental to or associated with rayon manufacture and for the conversion of these into spinning solutions from which further quantities of rayon yarn may be made. None of this work, however, has been carried beyond the experimental stage and has not reached pilot-plant testing. In contrast, emphasis has been placed on experimental and commercial plant runs directed toward the utilization of these cellulose solvents in the finishing of rayon, cotton, and mixture fabrics. The specific factors in terms of qualities of the cloths or fabrics have been those of transparency, stiffness or crispness, dimensional stability, and shrinkage control. Many of these attributes are particularly desirable in sheer materials, low-count fabrics, marquisettes, scrims, ninons, and curtains.

When rayon fabrics are treated with selected compositions of solutions containing caustic, zincate, and urea, the shrinkage characteristics are appreciably modified, there being a substantially reduced shrinkage by comparison with the normal shrinkage of the untreated fabric. The normal shrinkage is measured as the initial wash shrinkage following the procedure given in "Federal Specifications for Textiles; General Specifications, Test Methods, C.C.C.-T-191-A." In a typical example, spun rayon marquisette was run through a solution on a factory or mill scale of several thousand yards, the solution containing about 10 percent caustic, 2 percent zinc oxide, and 10 percent urea, at a rate of speed so that the fabric was immersed for about 5 seconds at room temperature, squeezed by means of rollers, and then passed directly onto a tenter frame or stretching apparatus. The goods were held on this frame at the desired width for a solution-action time of about 15 seconds. The term "solution-action time" refers to the period in which the solution was allowed to act on the cloth before the fabric was flushed with water. After complete washing at the desired width, the cloth was dried on the tenter frame.

In the original cloth the shrinkage warpwise was 10 percent and fillingwise was 13.1 percent. The treated cloth showed a shrinkage of only 1.3 percent warpwise and 2.7 percent fillingwise. In addition, visual characteristics of the treated cloth were appreciably altered. While the original cloth was somewhat fuzzy, the treated cloth had the fuzz removed

with the resulting cleaner thread outline and an over-all translucent appearance.

In other modifications of plant processing with variations in composition of the urea, zinc oxide, and caustic solutions, methods have been worked out for varying immersion times and their effect on the stiffness or crispness of the fabric. Stiffness tests were judged in terms of the force in grams exerted by the sample when bent to a 40-degree angle. Untreated samples, even including those containing fillers, might have stiffnesses in this test of the order of 0.4 gram or less. Typical treatments such as those with solutions containing as little as 1 percent zinc oxide with 10 percent caustic and 10 percent urea, with immersion times of 30 seconds, gave stiffness figures of 1 gram, while compositions of the same caustic and urea percentages with from 3 to 4 percent zinc oxide produced stiffnesses of the order of 1.3 to 1.4 grams. This stiffness is permanent to washing and in terms of crispness is especially desirable for sheer curtain materials such as marquisettes, ninons, and the like.

Further modifications of the finishing operations involve the production of translucency effects for simulated damasks. In such a procedure the fabric is first printed in a suitable design with a gum paste based on materials such as starch, British gum, or related materials to serve as a resist or a blocking-off substance. The fabric is then passed in open width through a sodium zincate-urea solution and allowed to pile up either in a J box or on a traveling belt for 0.5 to 5 minutes and is then fed to a tenter frame, stretched to the desired width, washed with fresh water, and neutralized if desired. The gum or resist substance is washed out and removed by conventional finishing-plant procedures and the cloth stretched to width in a tenter frame and dried. The pattern, in the terms of the open spaces not printed with resist solution, then appears as a translucent design, readily reproducible and controllable. These designs may be further enhanced if desired by dyeing processes which take advantage of the differences in degree of the dyeing affinity of the treated and protected portions of the fabric. The treating solutions are applicable on conventional finishing-plant equipment without the necessity of special machinery or corrosion-resistant materials of construction.

Analogous results have been achieved on spun rayon fabrics employing solutions containing approximately 9 percent caustic, 2.7 percent sodium stannate, and 10 percent urea, with immersion times of 5 seconds, followed by squeezing and solution-action times of 15 seconds on tenter frames before flushing with hot water, followed by drying. Shrinkage control in a typical mill run with the stannate-urea solutions shows figures on the original cloth of 10.3 percent warpwise and 11.9 percent fillingwise, and on the treated cloth the figures are 2.6 warpwise and 2.3 fillingwise. Similarly to the zincate-urea solutions, the treated cloth is cleaner, is defuzzed, has a sharp thread outline, and an over-all translucent appearance. Analogous to the figures given for the zincate-urea solutions, the stannate-urea solutions also impart stiffness characteristics of approximately the same order. Damask, shadow, and translucency design effects may be produced with the stannate-urea solvents as with the zincate-urea solutions. In general, however, on an economic basis the zinc compounds are much cheaper than those of tin and for this reason have found preference.

The discussion to this point has primarily concerned itself with regenerated cellulose. The zincate- and stannate-urea combinations show solvency effects on raw cellulose such as cotton, but these are of lower degree in terms of speed of solution than on regenerated celluloses. Modifications of treatment of cotton fabrics in terms of preliminary treatment have been developed, and these treated fabrics have had their qualities enhanced by action on the cloths of the zincate-urea and stannate-urea materials. The modification of the cotton fabric primarily concerns itself with controlled bleaching with conventional agents such as hypochlorite, peroxide, and oxidizing agents. Because of the patent situation at the present time, it is not possible to give all the details, but in typical cotton marquisettes which have been control-bleached and then treated with zincate-urea solvents, original fabrics—or, rather, normally finished fabrics—showing warp shrinkages of 15 percent and filling shrinkages of 12 percent have been stabilized and after treatment show warp shrinkages of 3 percent and filling shrinkages of 2.5 percent. Stiffness or crispness attributes may be added and transparency or defuzzing may be achieved.

Comparisons have been made with commercial sulfuric-acid methods. With the same fabric, tensile strength warpwise of a commercial sulfuric-acid-treated fabric showed 28.5 pounds in the finished cloth, while with the zincate-urea method the warpwise tensile strength was 28 pounds. The shrinkage on the sulfuric-acid-treated materials which were

commercially acceptable fabrics was 4.3 percent warpwise and 6.9 percent fillingwise. The same base fabrics which had been subjected to the zincate-urea operations showed shrinkages of 2.9 warpwise and 3.3 fillingwise. The stiffness of the sulfuric-acid-treated fabric was 0.58 gram compared to a value of 0.64 gram for the zincate-urea-treated material. Both fabrics were commercially acceptable and desirable and of equivalent sales appeal. The finishing operations were carried out in reference to the sulfuric-acid method in a plant which was well skilled in the procedure as a result of continuous practical use thereof. The zincate-urea procedure was carried out in a conventionally equipped finishing plant employing its ordinary equipment, inasmuch as it was not set up with the specially designed corrosion-resistant units necessary for the sulfuric-acid operation.

In cotton-finishing plants there has been large-scale use of the alkali-soluble hydroxyethyl celluloses as permanent finishes replacing starches and related agents which are removed to greater or less extent during washing of the fabric when it is made into garments or household articles. These cellulose finishes with fillers are employed for adding weight or opacity to fabrics or imparting hand and feel to lower-count fabrics so that they give the reaction of a higher count. Rayon mill wastes of a wide variety may be dissolved or dispersed in zincate-urea or stannate-urea solvents to give controlled viscosities and compositions in terms of cellulose, which solutions are applicable to the same finishing procedures for which the alkali-soluble hydroxyethyl celluloses have found wide application.

Large quantities of Army fabrics were made by "pigment dyeing," whereby insoluble pigments were dispersed in alkaline solutions of hydroxyethyl cellulose or cellulose solutions in sodium zincate prepared at low temperatures. These finishes are quite permanent to washing and the cleansing operations normally associated with their field or personal use. It can be appreciated that, if large quantities of them are available as a result of excesses over the military needs but their colors of khaki and various shades of olive drab are not too acceptable to civilian consumers, they present a challenge for retreatment and conversion into other colors. Stripping can be successfully accomplished by procedures involving the application of zincate-urea and stannate-urea cellulose solvents, while treatment even at low temperatures with sodium zincate is too slow and uneconomical. A similar situation exists for the removal of hydroxyethyl cellulose finishes with caustic at low temperatures.

Summary

It is apparent that our studies in connection with cellulose solvents have been directed toward obtaining the basic scientific information, but specifically directing its application to the treatment of textile yarns, threads, and fabrics, in the field embraced by the term "finishing." Finishing plants concern themselves ordinarily with the movement through processing stages of large yardages of goods, semi-continuously or continuously, so that the mechanical complications are always present. The basic processes, however, are essentially chemical, modified and coordinated with the mechanical and high-speed movement of the goods through the plant. It is desirable that the equipment and processes be as simple and controllable as possible. Treatment of textile fabrics of cotton, rayon, and related materials with cellulose solvents of the zincate-urea and stannate-urea type has been found to fit into this picture.

Effect of Ageing of the Alkali Cellulose on the Carboxyl Content of Rayons

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Contribution of the Chemical Research Department, American Viscose Corporation

In the manufacture of viscose rayon the alkali cellulose is allowed to age in contact with air for a definite period of time. During this ageing period oxygen is absorbed and extensive depolymerization of the cellulose occurs. It has generally been assumed that this depolymerization is due for the most part to oxidative cleavage of the cellulose chains, with a resultant increase in carboxyl content. Thus Ludtke [6] in an early study concludes that the carboxyl content of rayon yarns increases with increasing time of ageing of the alkali cellulose. Similarly, in describing the ageing process Heuser [*3a*] states: ". . . the reducing power first increases, then decreases, while the methylene-blue absorption, being indicative of the number of carboxyl groups, increases. These changes and the fact that they are much less pronounced when ageing takes place with the exclusion of air and are more marked when oxygen is given access indicate that ageing is a process of oxidation. . . ."

In the present study carboxyl contents were determined for rayon yarns which had been subjected to the normal amount of ageing and which had also been over-aged and under-aged. The yarn samples are typical "Tenasco," or high-strength yarns, which in this test series were made from a pulp base composed of a mixture of 50 percent high-alpha wood pulp and 50 percent cotton linters. For comparison, the carboxyl content of a typical sulfite wood pulp is also given. It may be noted that the values obtained for these pulps are in fair agreement with those reported by Husemann and Weber [5], who find glucose numbers * of 700–1000 for cotton and 90–130 for wood cellulose.

In summary, the data of Table I indicate that the carboxyl contents of various celluloses decrease in the order: cotton, high-alpha sulfite wood, sulfite wood. They indicate that wide variation in the time of ageing of the alkali cellulose is without any major effect on the carboxyl content of the final yarns. Furthermore, the carboxyl content of the final yarn appears to be largely determined by the carboxyl content of the pulp from which the yarn is made. Accordingly it may be concluded that the ageing of the alkali cellulose causes only a very moderate increase in carboxyl content, in spite of the known fact that considerable oxygen is absorbed in the process and extensive depolymerization occurs.

* The number of glucose anhydride units per carboxyl group.

Experimental Data

All analyses were made by a modification of Ludtke's [6] calcium acetate displacement method, in combination with the washing procedure of Neale and Stringfellow [7]. A 1-gram sample is allowed to stand in 0.5-percent hydrochloric acid for ½ hour, filtered through a sintered glass crucible, and washed repeatedly with distilled water until the washings are neutral to bromcresol purple. The sample is then transferred to a 100-ml. graduated cylinder, 50 ml. of 1.0 molar calcium acetate is added, and the whole is made up to 100 ml. with distilled water. The liquid plus cellulose is transferred to a 250-ml. glass-stoppered Erlenmeyer flask (Pyrex) and allowed to stand for one hour, with occasional shaking. The cellulose phase is then filtered out in a sintered glass crucible and a convenient aliquot of the filtrate is titrated to a phenolphthalein end-point with 0.01*N* sodium hydroxide. A blank run is necessary.

Discussion

As described, the data were obtained by a modification of the calcium acetate method. Since the results are at variance with those previously reported, a comparison of this analytical method with others available in the literature would seem to be indicated.

Methylene-blue pick-up has been widely used as an index of carboxyl content, but there is considerable evidence that this procedure is not generally reliable [7]. Schmidt *et al.* [9] have determined carboxyl contents by direct titration with alkali. Neale and

TABLE I. CARBOXYL CONTENTS DETERMINED BY THE CALCIUM ACETATE METHOD

Material	Ageing time	ml. 0.01 normal NaOH required per gram sample	Glucose units per carboxyl
Wood pulp, sulfite		4.75	130
Wood pulp, high-alpha sulfite		1.92	320
Tenasco rayon from above pulp, 150 den.	Normal	1.92	320
Tenasco rayon from above pulp, 300 den.	Normal	2.63	230
50–50 cotton-wood pulp blend		1.24	500
Tenasco rayon from above pulp, 300 den.	Normal	1.28	480
Tenasco rayon from above pulp, 300 den.	Normal	1.65	370
Tenasco rayon from above pulp, 300 den.	Normal	1.20	520 *
Tenasco rayon from above pulp, 300 den.	Two days under age	1.42	430
Tenasco rayon from above pulp, 300 den.	Two days under age	1.28	480
Tenasco rayon from above pulp, 300 den.	Two days under age	1.22	510 *
Tenasco rayon from above pulp, 300 den.	Two days over age	1.46	420
Tenasco rayon from above pulp, 300 den.	Two days over age	1.54	400
Tenasco rayon from above pulp, 300 den.	Two days over age	1.54	400 *
Averages:			
Pulp base, 50–50		1.24	500
Normal yarn		1.36	450
Under-aged yarn		1.36	450
Over-aged yarn		1.54	400
Theoretical, primary hydroxyl attacked		5.00	125
Theoretical, secondary hydroxyl attacked		7.00	89
Theoretical, Heuser's mechanism		10.00	62

* These samples were not desulfurized, to avoid possible removal of oxidized short-chain residues in the alkaline desulfurizing bath.

Stringfellow [7], however, conclude that this method is not satisfactory. Variations of the Schmidt procedure are (1) direct titration in pyridine and (2) in ethyl alcohol. Method (1) has been used by Unruh and Kenyon [10*a*], who do not find it satisfactory. A variation of the method involving back-titration in pyridine, however, appears to be reliable [10*a*].

The carbon dioxide-evolution method appears to be satisfactory [10*b*], but measures only combined uronic acids. Similarly the Neale and Stringfellow titration in the presence of sodium chloride [7] appears to be reliable.

The widely used calcium acetate method has been subjected to considerable criticism, particularly in the older literature. Thus Neale and Stringfellow [7] find it to be completely unsatisfactory. Likewise Heymann and Rabinov [4*a*] find that high concentrations of calcium acetate are needed for complete liberation of the acid, and under these conditions the end-points in the titration are "most unsatisfactory." These authors, however, conclude that the method is entirely satisfactory at lower calcium acetate concentrations and when used for relative determinations.

In comparing the calcium acetate method with the carbon dioxide-evolution method, Unruh and Kenyon [10*a*] report that they obtain results about 50 percent too low by the former method. These authors point out, however, that this finding is not in agreement with the earlier work of Yackel and Kenyon [11], who reported good agreement between the two methods. It may be added that this systematic study by Yackel and Kenyon indicated, in general, good reproducibility for the calcium acetate method, with relative insensibility to the factors of calcium acetate concentration, temperature, and time of contact of the cellulose with the calcium acetate solution.

Work recently published in the literature appears to have further resolved the objections raised to the calcium acetate procedure. Thus Heymann and Rabinov [4*b*] find excellent agreement between the results obtained with the calcium acetate and the Neale and Stringfellow procedures. Similarly, in a recent survey of the available analytical methods, Unruh and Kenyon [10*b*] select the calcium acetate method as one which may be employed with some assurance.

It will be noted that rather concentrated calcium acetate solutions were used in the present investigation. No difficulty was encountered, however, in determining the end-points. The analysis is admit-

tedly not an accurate one and deviations between individual determinations were quite high. Nevertheless, when the precautions suggested in Experimental Data above were followed and averages of three determinations were taken, very satisfactory reproducibility was obtained by independent operators in this laboratory.

Theoretical Carboxyl Formation

Bartell and Cowling [1] find that 100 grams of alkali cellulose take up 34 ml. of oxygen during ageing for 141 hours at 21°C, which is approximately confirmed by the results of Davidson [2]. Let us assume that the formation of one carboxyl group on a glucose anhydride unit requires 2 atoms of oxygen if the primary hydroxyl is attacked and 1½ atoms if the secondary hydroxyl is attacked. Assuming the former, one mol. of glucose anhydride (162 grams) requires 32 grams of oxygen to form the carboxyl group. From Bartell and Cowling's data, 100 grams of alkali cellulose take up $34 \times 32/22{,}400$ grams of oxygen, or 4.86×10^{-2} grams. Since the moist alkali cellulose/cellulose ratio is about 3, this is the amount of oxygen taken up by about 30 grams of cellulose.

Since 32 grams of oxygen are required to form one carboxyl group per mol. of glucose anhydride unit, $4.86 \times 10^{-2}/32 \times 30$, or 5×10^{-5}, are the equivalents of acid which would be liberated by 1 gram of cellulose if all of the oxygen taken up during ageing had reacted to form carboxyl groups. This is equivalent to a titer of 5.0 ml. of 0.01*N* sodium hydroxide, or 7.0 ml. if the secondary hydroxyl is attacked.

In Heuser's proposed mechanism [3*b*], one carboxyl is formed for every atom of oxygen absorbed, and the theoretical titer in this case would be 10.0 ml.

As indicated in Table I under "Averages," the result of the ageing of the alkali cellulose is only a very moderate increase in titer of some 0.30 ml. Although some deviation in individual determinations is indicated, the average deviation for all of the results is only 0.17 ml. Accordingly, when this titer of 0.30 ml. (with an average deviation of 0.17 ml.) is compared with the theoretical titer of 5.0–10.0 ml., it would appear that much less than 10 percent of the oxygen taken up during ageing has reacted to form carboxyl groups.

Recently Pacsu [8] has proposed a mechanism for the alkaline oxidation of cellulose which reconciles this discrepancy between the oxygen take-up and the apparent failure to form carboxyls. This investigator suggests that oxygen attacks the cellulose chain in the same manner as periodic acid, so that the dialdehyde type of oxidized glucose anhydride unit is formed. He suggests that this dialdehyde unit undergoes cleavage in the alkali normally present in alkali cellulose to form oxidized fragments and two cleaved cellulosic residues, each of which now ends in a hydroxyl group. Since the cellulosic residues terminate in hydroxyl groups, no increase in carboxyl content would evidently be expected.

Summary

Carboxyl-group determinations carried out on rayon yarns indicate only a very moderate increase in carboxyl content as a result of the ageing of the alkali cellulose. These data are in agreement with Pacsu's mechanism for the ageing process.

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Cellulose Studies

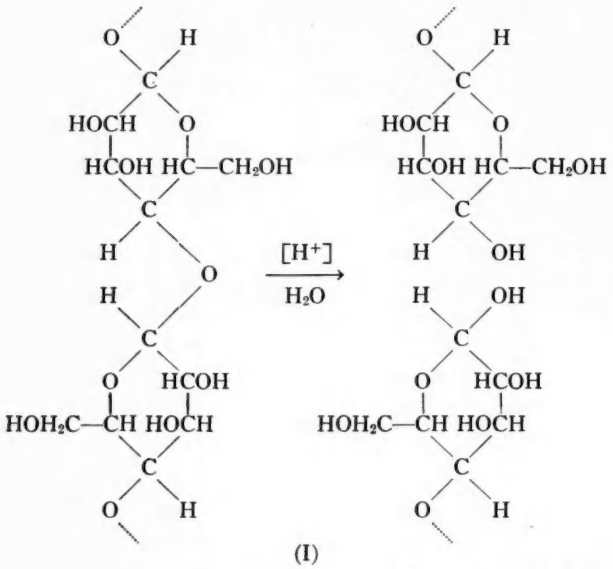
VII. The Nature of "Hydrocellulose"*

Lejaren Arthur Hiller, Jr.,† and Eugene Pacsu

Contribution from The Textile Foundation and the Frick Chemical Laboratory at Princeton University

IT is well known that acids rapidly attack cellulose fibers, causing severe damage. Even under relatively mild conditions, tensile strength is soon lost and the fibrous structure is decomposed to a powder. Under more drastic conditions, such as the use of concentrated mineral acids, cellulose can be completely dissolved.

These effects have been commonly interpreted [1, 2] as due to acid-catalyzed hydrolysis of the 1,4-glycosidic bonds of a cellulose chain molecule (I),



(I)

a process which, if continued to its ultimate limit, would result in the formation of glucose. This hydrolytic attack is considered to be completely random; thus if the attack is permitted to proceed only to a slight extent, the net effect of the treatment would be a diminution of the average degree of polymerization. The product of this partial reaction is termed "hydrocellulose." It is considered to be no more homogeneous in molecular size distribution than is the original cellulose.

Much experimental evidence has been accumulated which apparently supports this explanation. By most methods for estimating reducing groups, a "hydrocellulose" usually shows a greater reducing power than the original material from which it was prepared. This substantiates the hydrolysis theory, for, as can be seen from the above formula (I), every time a hydrolytic cleavage occurs, a new reducing group is formed. Also, hydrocelluloses show much lower viscosities, which, in line with Staudinger's equation relating viscosity to average molecular weight, would apparently also demonstrate that degradation of the molecular chains of cellulose has occurred. Furthermore, it has also been believed that cellulose fibers are attacked more severely on the surface than in the core. The reason usually given is that the surface molecules are more available for degradation.

We wished to apply to hydrocelluloses the reduc-

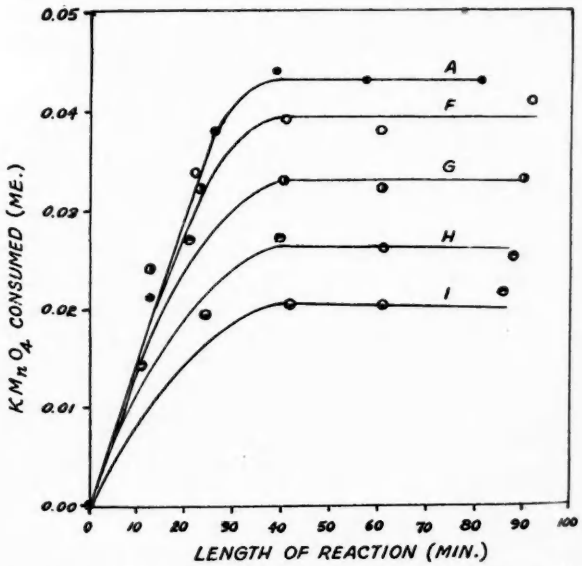


FIG. 1. *Hydrocelluloses prepared with sulfuric acid: reducing group content.*

* This is the seventh paper in a series—"Cellulose Studies." The other six have appeared in the October, 1945, and the March, April, June, July, and August, 1946, issues.

† Fellow of the Textile Research Institute.

TABLE I. HYDROCELLULOSE SAMPLES PREPARED

Sample	Material treated	Solution	Treatment time	Temp.	Physical appearance
A	Surgical cotton	—	—	—	—
B	Surgical cotton	0.5*N* H_2SO_4	3 hrs.	60°C	Apparently unchanged
C	Surgical cotton	1*N* H_2SO_4	3 hrs.	60°C	Quite brittle
D	Surgical cotton	3*N* H_2SO_4	3 hrs.	60°C	Powdery
E	Surgical cotton	5*N* H_2SO_4	3 hrs.	60°C	Very powdery
F	Surgical cotton	0.5*N* HCl	24 hrs.	20°C	Brittle
G	Surgical cotton	1*N* HCl	24 hrs.	20°C	Brittle
H	Surgical cotton	5*N* HCl	24 hrs.	20°C	Powdery
I	Surgical cotton	2*N* HCl	6 hrs.	60°C	Powdery
J	Viscose rayon	—	—	—	—
K	Viscose rayon	5*N* H_2SO_4	3 hrs.	60°C	Very powdery
L	Viscose rayon	10% lactic acid	0–24 hrs.	100°C	Quite brittle
M	Viscose rayon	Mixture of 10% acetic acid and 10% NaCl	0–24 hrs.	100°C	Quite brittle

ing group estimation using dilute potassium permanganate in acidic medium, which method was reported in Part V of this series [3]. We expected reactions that would confirm the above picture, but, instead, quite contrary results were obtained, necessitating considerable modification of the foregoing conception.

A number of different hydrocelluloses were prepared by means of standard procedures. The samples and the methods employed to prepare them are summarized in Table I. It will be noticed that there are three principal series of samples: one prepared with sulfuric acid at 60°C, the second set prepared with hydrochloric acid at 20°C, and the third set prepared with dilute organic acids at 100°C, giving three sets of materials treated increasingly severely within a comparatively mild acidic range. In cases where mineral acids were employed 30-gram samples were steeped in 1,500-ml. solutions. For the experiments with organic acids carried out by Mr. P. C. Mehta, Fellow of the Textile Research Institute, individual 1-gram samples were used. Each sample, after treatment with acid, was filtered, thoroughly washed, and dried in an oven at 50°C. The reducing content was then determined by means of potassium permanganate according to the method previously described [3]. The results are shown in Table II and in Figures 1, 2, and 3.

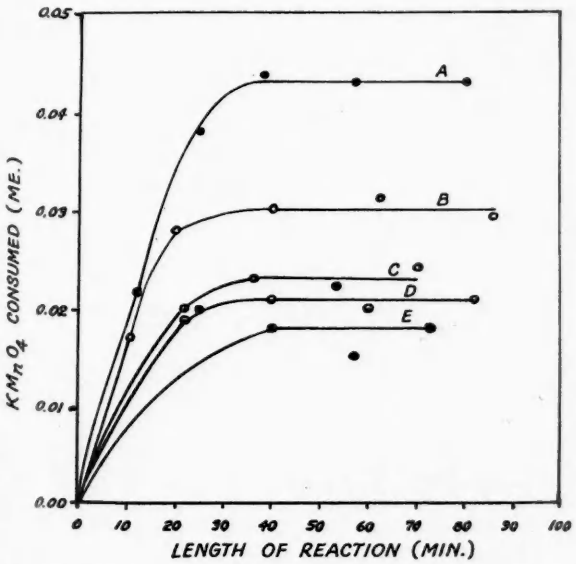


FIG. 2. *Hydrocelluloses prepared with hydrochloric acid; reducing group content.*

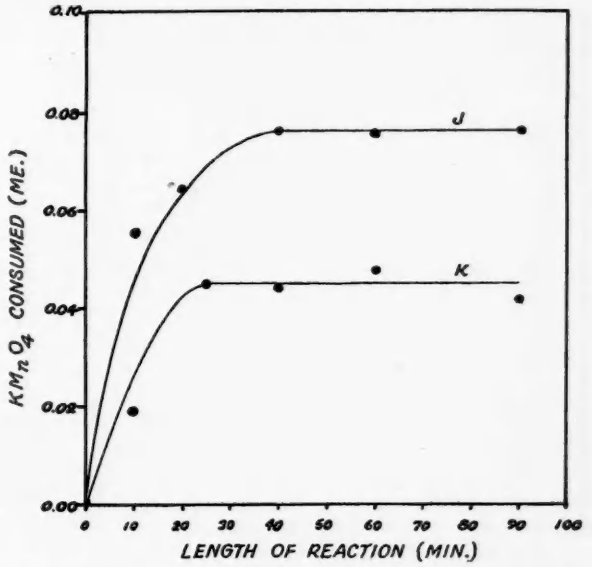


FIG. 3. *Rayon and rayon hydrocellulose; reducing group content.*

TABLE II. REDUCING POWER OF HYDROCELLULOSES BY POTASSIUM PERMANGANATE

1. *Sulfuric-Acid-Treated Samples*

Cotton samples

Reagents: 0.0803*N* potassium permanganate
0.0544*N* ferrous ammonium sulfate
0.25*N* sulfuric acid

	Sample No.	Length of reaction (min.)	Weight of sample (g.)	Total volume $KMnO_4$ (ml.)	Total volume $Fe(NH_4)_2(SO_4)_2$ (ml.)	Milli-equivalent $KMnO_4$ added	Milli-equivalent $Fe(NH_4)_2(SO_4)_2$ added	Milli-equivalent oxygen used up	Milli-equivalent oxygen used up per g.
A.	—	—	—	8.85	13.09	0.711	0.712	−0.001	—
	1	12	1.000	8.90	12.75	0.715	0.694	0.021	0.021
	2	25	1.244	8.92	12.30	0.716	0.669	0.047	0.038
	3	38	0.923	8.87	12.34	0.712	0.671	0.041	0.044
	4	57	1.171	9.27	12.75	0.744	0.694	0.050	0.043
	5	80	0.891	9.08	12.70	0.729	0.691	0.038	0.043
B.	1	11	0.955	8.86	12.78	0.711	0.695	0.016	0.017
	2	20	0.953	8.93	12.69	0.717	0.690	0.027	0.028
	3	40	0.915	8.75	12.43	0.703	0.676	0.027	0.030
	4	62	0.841	8.79	12.50	0.706	0.680	0.026	0.031
	5	86	0.877	8.77	12.48	0.704	0.679	0.025	0.029
C.	1	22	1.092	8.97	12.83	0.720	0.698	0.022	0.020
	2	36	1.196	8.61	12.21	0.691	0.664	0.027	0.023
	3	53	1.198	8.88	12.62	0.713	0.687	0.026	0.022
	4	70	1.231	9.00	12.73	0.723	0.693	0.030	0.024
D.	1	21	1.234	8.85	12.62	0.711	0.687	0.024	0.019
	2	40	1.411	8.87	12.54	0.712	0.682	0.030	0.021
	3	60	1.006	8.93	12.81	0.717	0.697	0.020	0.020
	4	82	1.070	8.97	12.84	0.720	0.698	0.022	0.021
E.	1	25	1.520	8.68	12.25	0.697	0.666	0.031	0.020
	2	40	1.235	9.02	12.90	0.724	0.702	0.022	0.018
	3	57	1.456	8.64	12.34	0.693	0.671	0.022	0.015
	4	73	1.365	9.37	13.37	0.752	0.727	0.025	0.018

2. *Hydrochloric-Acid-Treated Samples*

Cotton samples

Reagents: 0.0733*N* potassium permanganate
0.0857*N* ferrous ammonium sulfate
0.25*N* sulfuric acid

F.	—	—	—	8.68	7.42	0.636	0.630	0.000	—
	1	21	0.940	8.82	7.18	0.647	0.615	0.032	0.034
	2	40	1.143	8.75	6.97	0.641	0.597	0.044	0.039
	3	60	1.536	8.86	6.89	0.649	0.590	0.059	0.038
	4	91	1.651	8.83	6.77	0.647	0.580	0.067	0.041
G.	1	11	1.117	8.40	6.87	0.616	0.589	0.027	0.024
	2	22	1.232	8.52	6.83	0.625	0.585	0.040	0.032
	3	40	1.213	8.60	6.88	0.630	0.590	0.040	0.033
	4	60	1.523	9.45	7.51	0.693	0.644	0.049	0.032
	5	89	1.029	8.30	6.70	0.608	0.574	0.034	0.033

TABLE II. REDUCING POWER OF HYDROCELLULOSES BY POTASSIUM PERMANGANATE—*Continued*

2. Hydrochloric-Acid-Treated Samples—Continued

	Sample No.	Length of reaction (min.)	Weight of sample (g.)	Total volume $KMnO_4$ (ml.)	Total volume $Fe(NH_4)_2(SO_4)_2$ (ml.)	Milli-equivalent $KMnO_4$ added	Milli-equivalent $Fe(NH_4)_2(SO_4)_2$ added	Milli-equivalent oxygen used up	Milli-equivalent Oxygen used up per g.
H.									
	1	10	1.911	8.50	6.96	0.623	0.596	0.027	0.014
	2	20	1.373	8.26	6.51	0.605	0.558	0.037	0.027
	3	39	1.498	8.40	6.72	0.616	0.576	0.040	0.027
	4	60	1.406	8.68	7.00	0.636	0.600	0.036	0.026
	5	88	1.418	8.69	7.01	0.637	0.601	0.036	0.025
I.									
	1	24	1.046	8.83	7.32	0.647	0.627	0.020	0.019
	2	41	1.111	8.52	7.05	0.625	0.603	0.022	0.020
	3	60	0.991	8.68	7.19	0.636	0.616	0.020	0.020
	4	85	1.277	8.83	7.23	0.647	0.620	0.027	0.021
				Rayon samples					
				Reagents: 0.1076*N* potassium permanganate					
				0.0585*N* ferrous ammonium sulfate					
				0.25*N* sulfuric acid					
J.									
	—	—	—	7.97	14.70	0.858	0.858	—	0.000
	1	10	1.000	7.68	13.18	0.826	0.771	—	0.055
	2	20	1.000	7.67	13.01	0.825	0.761	—	0.064
	3	40	1.000	7.72	12.91	0.831	0.755	—	0.076
	4	60	1.000	7.97	13.38	0.858	0.783	—	0.075
	5	90	1.000	8.15	13.69	0.877	0.801	—	0.076
K.									
	1	10	1.000	7.91	14.23	0.851	0.832	—	0.019
	2	25	1.000	7.69	13.36	0.827	0.782	—	0.045
	3	40	1.000	8.08	14.11	0.869	0.825	—	0.044
	4	60	1.000	7.81	13.55	0.840	0.793	—	0.047
	5	90	1.000	7.85	13.73	0.845	0.803	—	0.042
				3. Organic-Acid-Treated Samples					
				Rayon samples					
				Reagent: 10% lactic acid					
L.*									
	L_2	40	1.000	—	—	2.3801	2.3064	—	0.073
	L_6	40	1.000	—	—	2.3710	2.3064	—	0.064
	L_{12}	40	1.000	—	—	2.3620	2.3064	—	0.055
	L_{24}	40	1.000	—	—	2.3530	2.3064	—	0.044
				Reagent: 10% acetic acid in 10% sodium chloride					
M.*									
	M_2	40	1.000	—	—	2.3607	2.3064	—	0.054
	M_6	40	1.000	—	—	2.3336	2.3064	—	0.027
	M_{12}	40	1.000	—	—	2.3504	2.3064	—	0.044
	M_{24}	40	1.000	—	—	2.3426	2.3064	—	0.036

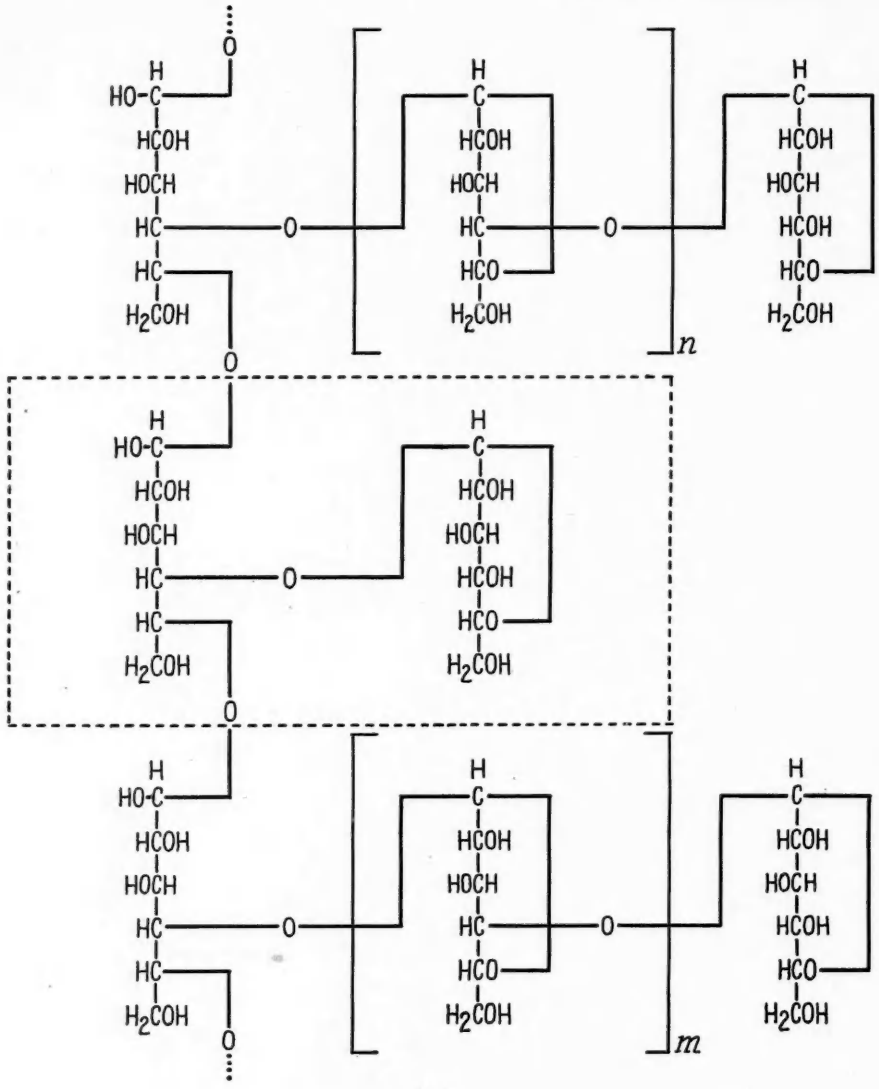
* The subscripts designate the time of heating in hours of the samples at 100° in the acidic media employed.

We were surprised to find that the mild acid treatment employed apparently decreased the reducing power of cellulose. Subsequent treatments of samples with acids under somewhat more drastic conditions caused a much smaller drop in reducing power than was anticipated from the initial effect. This appears to be a consistent process—the more energetic the treatment within the acidic region employed, the less the reducing power.

That acids caused a greater polymerization of cel-

lulose could not be accepted as a rational explanation. The easy formation of hydrocellulose by treatment with aqueous organic acids such as 10 percent lactic or acetic acid, substituting for acidic perspiration or sweat, cannot be reconciled with the comparative resistance of glucopyranosidic linkages in cellulose to the hydrolytic action of such agents. These conclusions, together with the results of our experiments to be discussed in the next paper of this series dealing with the viscosity of cellulosic materials in 85 percent phosphoric acid, led us to believe that, beside normal 1,4-glycosidic bonds, cellulose must contain another type of linkage which is extremely sensitive to acid-catalyzed hydrolysis. The concept we finally arrived at was as follows.

A cellulose fiber is a composite of chain molecules ranging in size from extremely long chains down to a few which are probably glucose or cellobiose. The size range fits a typical distribution curve, the average-size chain molecules being present in the largest numbers. These primary chain molecules with their terminal open-chain glucose units form still larger, secondary chain molecules by means of semiacetal linkages involving open-chain molecules of glucose, cellobiose, and the larger polymer structures. Part of such a structure is shown in formula II.



(II)

The secondary chain molecules are built up in three dimensions eventually to form the visible fiber, which obtains its strength mainly from hydrogen

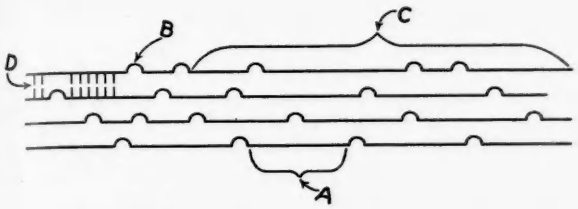
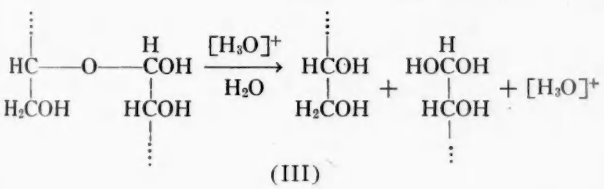


FIG. 4. *The structure of crystalline cellulose fiber. A—Cellulose "molecule" having only 1,4-glycosidic linkages. Primary chain molecule. B—Semiacetal linkages with the participation of open-chain simple sugars. C—Secondary chain molecules* (cf. *formula II*). *D—Hydrogen bonds.*

bonding in lateral directions. A schematic diagram of a crystalline region of a fiber shows this structure (Figure 4).

The primary action of acids is not hydrolysis of the 1,4-glycosidic bonds. While it cannot be denied that this type of hydrolysis will occur if the reaction is sufficiently drastic and prolonged, the properties commonly attributed to hydrocellulose do not arise from this attack. Rather, it is the hydrolysis of the semiacetal linkages (III) and the rupture of a number of hydrogen bonds which normally hold the fiber together that causes the loss of tensile strength and disintegration of the material into a powder.



(III)

The semiacetal bonds are far less stable toward oxonium ions than glycosidic bonds and are, therefore, much more easily hydrolyzed in acidic media. Once they are ruptured, the individual primary chain molecules are free to leave the fiber as soon as hydrogen bonding is broken. It is reasonable to assume that the number of hydrogen bonds holding a particular chain in the fiber is proportional to the length of that chain. Since the hydrogen bonds are randomly broken, it is more likely that small, short molecules will be freed first, for the simple reasons that they are held by fewer bonds and that they are more soluble in water. Thus the smallest molecules are selectively freed first from the less crystalline areas of the fiber, and are washed away, leaving a residual mass of larger molecules still held together by unbroken hydrogen bonds. The more drastic the action of the acid, the more hydrogen bonds within the fiber are ruptured, and as a consequence more and more molecules are freed, larger and larger ones being liberated, eventually from the crystalline regions of the fiber as the process continues. This can be easily pictured if one thinks of the distribution curve of cellulose molecules being progressively chewed up from the small-size end (Figure 5).

The experimental facts thus far presented fit into this picture. The decrease in the original reducing power which corresponds to the total number of semiacetal linkages is caused by the loss of small molecules. Since these small molecules, on leaving the fiber after hydrolysis of their semiacetal linkages, do not create new reducing groups, the reducing power of the hydrocellulose becomes less than that of the original material. The average degree of polymerization of the residual then becomes effectively higher.

The amount of material lost as a result of the initial attack of acids is minute by comparison with the weight of the original sample. We could detect no weight loss at all on the scales. If the small molecules were not selectively removed, there would be no decrease in reducing power, but the latter would remain at its original value.

The rupture of a number of hydrogen bonds is also responsible for the loss of physical structure and strength. The whole structure is loosened and weakened. Furthermore, the removal of small molecules leaves gaps in the structure, causing weak spots. When the gaps are sufficiently numerous, the fiber is

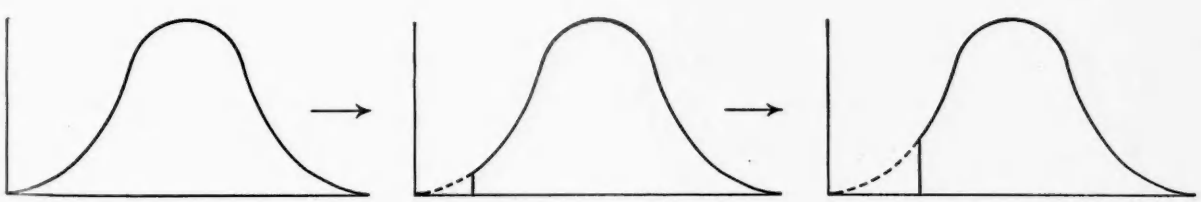


FIG. 5. *Progressive change in the distribution curve by freeing of small molecules.*

bound to fall apart simply because the remaining primary chain molecules are too scattered and the structure is too flimsy to hold together.

If this view of cellulose structure be correct, then the lost reducing power of a cellulose should be found in the acid solution used for degrading the fiber. The filtered acid solution employed in preparing one of the hydrocelluloses previously mentioned (Sample C) was tested for reducing power according to the method of Kline and Acree [4].

The acid solution and first washing were carefully neutralized with sodium hydroxide, the final solution being barely acidic. The volume of the solution was then reduced to 360 ml. by slow evaporation on a water bath. Fifty ml. of this solution (it must not contain phenolphthalein indicator!) were used for analysis according to Kline and Acree [4]. The data are summarized in Table III.

The amount of reducing power lost by cotton during its conversion to hydrocellulose was found to agree quite well with the reducing power of the solution. Moreover, a check on the iodine value obtained by titrating with standard alkali the free acid left after completing the iodine titration [5] indicated that for every 2 equivalents of iodine used, 3 equivalents of acid were produced. In other words, the rate of volumes of 0.1*N* alkali to 0.1*N* iodine consumed in the experiment was 1.31 : 0.941, which is very nearly 3 : 2, as it should be if the hypoiodite oxidation reaction be confined to the aldehyde group alone.

From the lost reducing power, 0.0225 milliequivalent per gram of cotton as found in the sulfuric acid solution, the ratio of glucose-anhydride units to small molecules, such as glucose, cellobiose, etc., with acid-sensitive semiacetal linkages in the original cotton is calculated to be 548 : 1. The significance of this result in light of the latest conception of the German school concerning the chemical structure of cellulose [6] will be discussed in a forthcoming article of this series.

Because of the conflict of our results relating to the end-group analysis by the potassium permanganate method with those obtained by other methods, determinations were made on some of our hydrocellulose samples using the hypoiodite method, which, like most methods, is claimed to show increased aldehyde content for hydrocelluloses [7]. The results of these experiments, presented in Table IV, do apparently show higher values for reducing power than does the potassium permanganate method. But the values show no consistent pattern and, what is worse, the reaction does not stop. It was pointed out in Part II of this series [8] that the supposed reducing power continues to increase the longer the reaction is run. We believe that the greater reactivity of hydrocelluloses toward reagents such as hypoiodite is due to the free, open-chain aldehyde end-groups which allow the molecule as a whole to be more readily attacked by the alkali of the oxidizing agent. Therefore, the hypoiodite values are not a measure of increased number of reducing end-groups, but merely a measure of the greater ease of "over-oxidation" of the primary chain molecules in a hydrocellulose.

Summary

1. Hydrocelluloses were prepared by standard procedures. These were subjected to reducing-group determinations using the potassium permanganate method. It was found that the reducing power of a hydrocellulose was less than that of the cotton from which it was prepared.

2. A new theory of the acid treatment of cellulose has been presented. This theory claims that weak acids do not hydrolyze 1,4-glycosidic bonds but rather hydrolyze semiacetal bonds which connect the primary chain molecules together to give rise to secondary chain molecules.

3. This process results in a leaching-out of the

TABLE III. TESTING MOTHER LIQUOR USED IN PREPARING HYDROCELLULOSE (*C*) FOR REDUCING POWER BY KLINE AND ACREE'S METHOD [4]

Weight of cotton sample	30 g.
Final volume of solution	360 ml.
Volume of solution to be titrated	50 ml.
Volume of 0.1*N* NaOH added	6.65 ml.
Volume of 0.1*N* I_2 added	4.077 ml.
Volume of 0.1*N* HCl added	7.39 ml.
Volume of 0.1*N* $Na_2S_2O_3$ used up	3.136 ml.
Volume 0.1*N* NaOH for back titration	2.05 ml.
Milliequivalent I_2 consumed for 50 ml.	0.0941
Milliequivalent I_2 consumed for 360 ml.	0.677
Milliequivalent I_2 consumed per g. cotton	0.0225
Reducing power of cotton from $KMnO_4$ (Table II, A)	0.043 me./g.
Reducing power of hydrocellulose from $KMnO_4$ (Table II, C)	0.023 me./g.
Reducing power lost	0.020 me./g.
Reducing content found in sulfuric acid solution	0.0225 me./g. cotton

TABLE IV. REDUCING POWER OF HYDROCELLULOSES BY HYPOIODITE

Reagents: 0.03*N* iodine
0.1*N* hydrochloric acid
0.02*N* sodium thiosulfate
10 ml. borate buffer (pH 9.2)

Sample No.	Weight of sample (g.)	Total volume I_2 (ml.)	Milli-equivalent I_2 added	Length of reaction (hrs.)	Total volume HCl (ml.)	Total volume $Na_2S_2O_3$ (ml.)	Milli-equivalent $Na_2S_2O_3$ added	Milli-equivalent I_2 used up per g.	Milli-equivalent $KMnO_4$ used up per g. (from Table II)
E	1.0	20.46	0.614	6.0	15.00	27.94	0.559	0.055	0.018
F	1.0	20.46	0.614	3.0	15.00	28.17	0.563	0.051	—
F	1.0	20.46	0.614	4.0	15.00	27.60	0.552	0.062	—
F	1.0	20.46	0.614	5.0	15.00	27.76	0.555	0.059	—
F	1.0	20.46	0.614	6.0	15.00	27.19	0.544	0.070	0.039
G	2.0	20.46	0.614	4.0	15.00	28.30	0.566	0.024	0.033
H	1.0	20.46	0.614	6.0	15.00	26.77	0.535	0.079	0.026
I	1.0	20.46	0.614	6.0	15.00	27.18	0.544	0.070	0.020
J	1.0	20.38	0.612	4.0	15.00	28.07	0.561	0.051	—
J	1.0	20.38	0.612	5.0	15.00	28.07	0.561	0.051	—
J	1.0	20.38	0.612	6.0	15.00	27.55	0.551	0.061	—
J	1.0	20.38	0.612	7.5	15.00	27.03	0.541	0.071	0.076

smaller molecules, such as glucose, cellobiose, etc., leaving a residue of larger primary chain molecules.

4. The loss of physical structure is due to breaking of a number of hydrogen bonds and to loss of small molecules.

5. The lost molecules, 1 for every 548 glucose-anhydride units, which were determined by their reducing power, were found in the acid solution used for the preparation of hydrocellulose.

6. The hypoiodite estimation gave irregular and high values as anticipated from the results presented in Part II of this series. The high values are explained as partly due to the sensitivity of the free, open-chain aldehyde groups in hydrocellulose toward the alkali of the hypoiodite reagent.

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Outline of Low Alkali Viscose Process*

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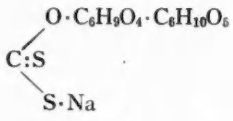
IT is believed generally that the consumption of caustic soda in the manufacture of rayon yarn and staple by the viscose process amounts to 1 pound of soda to 1 pound of finished product; that is, 100 percent to output. Thus in February, 1944, the average consumption of caustic soda at 12 factories in Japan was 85 percent to output. From the theoretical point of view, however, I pointed out that the consumption must be diminished considerably. According to the chemical formula of cellulose xanthate,



the ratio of Na to cellulose corresponds to 23:324; hence, 12 parts caustic soda per 100 parts cellulose. This suggests to us the practical possibility of reducing the consumption of caustic soda.

From the results of a series of fundamental experiments we could show that the viscose, in which the ratio of caustic soda to cellulose is 25:100, would have sufficient stability for practical use. To reach this limit in a practical way, however, seems to be difficult, certainly, as the above experiments were all carried out with purified xanthate. Nevertheless this substantiates our opinion that the consumption must be reduced further.

For such an excessive introduction of caustic soda into this process the following two steps are responsible:

(*a*) Squeezing (compression) of alkali cellulose and
(*b*) Preparation of spinning liquid

The mercerized pulp sheets are usually compressed and squeezed by means of the motion of a hydraulic ram until their wet weight reaches approximately three times the original air-dry weight, this being a universal practice. However, if we assume the following chemical formula for alkali cellulose (Na-Cell I):

$$C_6H_{10}O_5 \cdot NaOH \cdot 4H_2O,$$

we could squeeze until the pulp is 1.69 times the original bone-dry weight of the cellulose. The excessive caustic soda which remains on account of the low pressure acts by no means effectively, but quite harmfully, troublesome compounds such as sodium thiocarbonate being produced. Thus from the practical point of view, I suggested that it may be profitable to squeeze until the sheets are about twice the original pulp weight.

The xanthate is dissolved customarily in dilute caustic soda solution so as to obtain viscose of the desired composition—for example, cellulose 8 percent and total alkali as caustic soda 6 percent. Interestingly, it was found out by the aid of experiments that the additional caustic soda also can be diminished considerably, if we prepare purer xanthate by means of stronger squeezing of alkali cellulose.

The viscose thus obtained, containing 8 percent cellulose and 4.0–4.5 percent caustic soda, was spun with coagulating baths containing

sulfuric acid	40–60 g./L. (3–5%)
sodium sulfate	200–300 g./L. (15–25%)
zinc sulfate	10–20 g./L. (1–2%)

A particular feature of the above spinning bath consists of its lower content of sulfuric acid, while the baths which are generally employed contain as much as 100–150 g./L. (8–12 percent) of sulfuric acid.

Considerable experimentation and improvement of methods resulted in fibers produced with lower consumption of chemicals.

Summary of Experiments

1. Mercerized pulp sheets are squeezed until they are 2.3–2.0 times their original dry weight, instead of 3 times.

* Dr. Horio is a professor in Kyoto Imperial University and Director of the Institute of Fiber Chemistry.

This paper, which he wrote in English, was given by him to H. Wickliffe Rose as a member of the Textile Mission to Japan.

2. The xanthate is dissolved with more dilute caustic soda solution. An example of the constitution of viscose is: cellulose 8 percent and total alkali as caustic soda 4.0–4.5 percent instead of 6.0–7.0 percent.

3. The above viscose is spun with a bath containing a smaller quantity by far of sulfuric acid, say 40–80 g./L. (3–6 percent).

4. If this process were practiced, the consumption of caustic soda would be reduced to about 50 percent to output of yarns and fibers, reckoning the losses in the normal working. On the other hand, the consumption of sulfuric acid may be diminished to a half or less.

The above experiments were carried out on a small scale, in which a batch unit is 1 pound of pulp. On May 5 and 6, 1944, the results were disclosed to the public at Tokyo. The majority of factories endeavored to use this new process. It happened, however, that some troubles occurred in the strengthening of the squeezing; hence the desired compression was not reached. (There was damage to the steep presses and pumps.) At present, the compression varies from 2.7 to 2.4 in accordance with the ability of the machines. The consumption of caustic soda is estimated at about 70 percent to the finished yarns and fibers, instead of the former consumption of 85 percent or more. A further improvement appears to be impossible, as long as the present equipment is employed. (At Saijo Factory, Kurashiki Kenshoku K.K., squeezing up to 2.4 times was achieved and the consumption of caustic soda was reduced to 60 percent or less to output, at the end of January, 1945.) The consumption of sulfuric acid is much less.

The troubles may be overcome by the reconstruction of the steeping, compressing, and shredding machinery, for which we have several plans. I hope earnestly that these can be realized in the near future for the sake of practical manufacturing.

November 3, 1945

Manufacture of Tire Cords from Spun Rayon Yarn*

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RAYON tire cords are superior to cotton cords in their resistance to heat, especially in impact strength at higher temperatures than 100°C, and, accordingly, have better durability in practical use.

Because of this, viscose rayons with high tenacity have been recently employed for the manufacture of heavy tires.

In spite of the high tenacity, however, rayon cords cannot exert their effect sufficiently, because of the lack of adherence to rubber. On some experimental bases it could be estimated that the adhering power of rayon cords to rubber is only 40–45 percent of that of cotton cords.

This can be attributed to the smooth surface of rayon cords, and to make good this deficiency, some resinous substances have been employed. It happened, however, that these substances are not elastic enough to prevent the cords and the rubber from separating, especially at the time when tires are extremely deformed.

Moreover, the high twisting, which is usually adopted on account of higher elasticity of the cords, is not favorable to making good use of the inherent tenacity of yarns.

Our preliminary tests indicated that the tensile strength of the high-twist rayon cords amounted to half of the strength, calculated from the strength of a single filament and the count of the cords, while the elasticity was not improved remarkably.

From this standpoint we have attempted to study the application of viscose staple fibers to tire cords (hereafter referred to as spun rayon cords).

As raw material, viscose staple fibers, manufactured by Prof. M. Horio's "two-bath process," † were employed; tensile strength was higher than 3.0 g./den., staple length being 1½–2 inches.

First of all, we have investigated the relations between twist numbers and strength of filaments, threads, plies and cables in a wide range, and could find some fundamental relations, which indicated the full promise of spun rayon cords. The results of this research are summarized as follows:

1. Twisting of a single filament causes remarkable decrease in its tensile strength. This peculiar characteristic, differing from cotton, can be explained easily if we consider the shape and structure of rayon filament, which may be compared possibly to a rod, surrounded by rigid skin.

2. In order for the tensile strength of spun rayon to be higher than 50 percent of the value, estimated from original strength of the filament, twist numbers in each spinning stage must not exceed 10 turns per inch.

3. The resistance of yarns and cords to folding (double folding strength) decreases also remarkably with the increase of twist numbers in each spinning stage.

4. As for the direction of twisting, ZZS gives better results than ZSZ, if the twist numbers of both are equal in each spinning stage.

Therefore, referring to the tensile and folding strength, it could be concluded that the lower the twisting, the higher the utilization of the original strength of the fiber. But the lowest limit of single twist, practically realizable, has to be determined by the spinning machine; this is now about 8 turns per inch.

Considering the other properties, such as elasticity, elongation, and solidity, which are also important for tire cords, we cannot lower the ply and cable twists indefinitely.

When the single (thread) twist is 10 turns or less per inch, ply twist of 5–7 and cable twist of 7–9 (each per inch) may be most favorable for balancing of those mechanical properties required for tire cords.

* The work reported in this paper was done under the direction of Prof. M. Horio of this institution, who wrote the paper in English and gave it for publication to H. Wickliffe Rose as a member of the Textile Mission to Japan. A paper by Professor Horio appears on page 498 of this issue.

† Reported in a former paper in full detail [reference not available]. All of the rayon tire cords which have been manufactured in Japan until today [November, 1945 (?)] have been made of high-tenacity rayon spun by this process.

TABLE I.

	Construction	Twist numbers (per inch)	Tensile strength	Tensile strength measured immediately after heating to 150°C	Elongation		Folding test (double folding numbers until break)	Vibrating test (minutes until breaking)
					Until break	Under 4.5 kg. load		
Low-twist spun rayon cord		ZZS	Kg.	Kg.	%	%		
I	18s/5/3	8/5/7	9.8	11.5	22	11	2500	560
II	18s/5/3	10/6/9	8.7	10.3	25	13	2000	450
III	22s/5/3	14/5/7	7.0	—	26	14	1700	—
High-twist spun rayon cord								
I	18s/5/3	10/20/10	6.5	—	26	13	800	—
II	22s/5/3	16/12/8	4.5	—	26	14	800	—
III	22s/5/3	16/20/10*	3.7	—	24	12	500	30
Rayon yarn cord								
I	275 den./5/3	3/20/10	8.0	—	26	13	200	480
II	275 den./4/3	3/20/10	7.2	—	28	14	300	—
"Cordura" cord	275 den./4/3	3/20/10	7.6	—	27	14	700	—
Cotton cord								
I	18s/5/3	16/20/10	10.5	7.0	35	18	—	—
II	20s/5/3	16/20/10	9.7	6.6	33	16	2000	—
III	22s/5/3	16/20/10	8.2	—	32	16	3500	200

* Corresponding to the best condition for cotton cords.
Folding test: Measured by Schopper's paper-testing apparatus under 2 kg.
Vibrating test: Measured under 2.5 kg. cycle loading with high frequency (1,500 cycles/min.).

We have tested more than a dozen samples of spun rayon cords, twisted in such low numbers, which were prepared for us by courtesy of two representative cotton mills in Japan.

Some average values of mechanical properties of such low-twist spun rayon cords which we have obtained are listed in Table I, being compared with other types of tire cords.

The reason we adopted in low-twist spun rayon cords the thread count 18s instead of 22s is as follows: The count of low-twist cords (cables) is usually larger than that of high-twist; for example, the counts of the low-twist spun rayon cords I and II (in Table I) are almost equal to that of cotton cord II. And the gages (diameters) of low-twist spun rayon cords I and II are nearly similar to that of rayon yarn cord I or cotton cord III.

The adherence of low-twist spun rayon cords to rubber is as good as could be expected, but yet inferior to cotton cords, as is shown in Table II.

It was warranted by some tire manufacturers that the low-twist spun rayon cord might be satisfactory with respect to adhering power, too, if preliminary soaking in gasoline-gum or the like were employed.

Thus we have assured that the low-twist spun rayon cord is very suitable for tire manufacture, especially because of its superior mechanical properties, and we had intended to test its durability, practically, by making it up into tires.

But we are sorry to say that the rubber factory, with which we were keeping touch, was destroyed by bombing just before the tires were to undergo running tests, and the cotton mills, where these low-twist spun rayon cords had been spun and woven on a semi-industrial scale, were also burned out immediately following the former event.

TABLE II.

	Cotton cord	Spun rayon cord	Rayon yarn cord
Cleaving test	150%	75%	43%
Pulling test	100%	92%	76%

Measured without any treatments of special adhesives.

Wear-Resistance of Apparel Textiles, II

Laboratory Evaluation of Military Fabrics and Correlation with Combat Course Tests

Ernest R. Kaswell

Fabric Research Laboratories, Inc., Boston

Portion of a research program on the Wear-Resistance of Apparel Textiles *sponsored by the Office of The Quartermaster General and the National Research Council, and conducted by the Textile Division of the Massachusetts Institute of Technology, Cambridge, and the Fabric Research Laboratories, Inc., Boston, Massachusetts.*

Part I, "Tests of Military Fabrics on Quartermaster Combat Course," appeared in the September, 1946, issue.

VIII. Laboratory Abrasion Studies

While the Combat Course experiments were in progress, the identical twill, H.B.T., and sateen fabrics were being studied in the laboratory. Their physical properties and abrasion-resistance as determined by the M.I.T. and Taber abrasers were measured.

The major problem in the use of laboratory abrasion testers is the interpretation of results.

The following physical properties have been suggested as criteria of abrasion-resistance: strength, visual appearance, thickness, weight, light transmission, air permeability, color, and cycles to form a hole.

All have been investigated in this and other programs.

Results show that reduction in tensile strength provides the best known criterion for measuring extent of abrasion damage. The method consists of abrading portions of a fabric for varying numbers of cycles and determining resulting strength losses. A graph of percent loss in strength versus abrasion cycles is then plotted; the curve depicts the abrasion-resisting properties of the fabric.

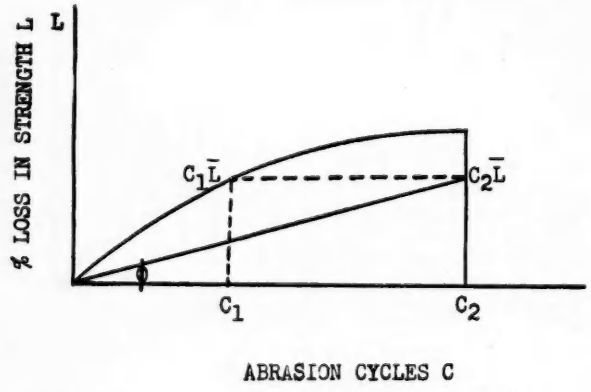


FIG. IX-1. *Percent loss in strength versus cycles.*

Using such graphs, laboratory abrasion destructive indices may be calculated in exactly the same manner as shown for the Combat Course. However, in this investigation, instead of calculating laboratory D.I.'s at each cycle station, a modified D.I. was calculated only for the highest cycle station—namely, at 800 abrasion cycles on the M.I.T. and 1,800 cycles on the Taber Abraser. This was accomplished by determining the area under the percent-loss-in-strength-versus-cycles curve, calculating the mean percent-loss-in-strength ordinate, and measuring the slope to that mean when it was moved to the cycle in question.

Graph IX-1* demonstrates the calculation of the laboratory D.I. in exactly the same manner that Graph IV-6 explained the Combat Course D.I.

$$L = f(C)$$

$$\text{Area } A = \int_0^C L\,dc = \int_0^C f(C)\,dc$$

$$\text{Mean ordinate } \bar{L} = \int_0^{C_2} \frac{f(C)\,dc}{C_2}$$

(mean percent strength loss)

* The graphs, charts, tables, and photomacrographs reproduced here have been chosen as representative of the complete series.

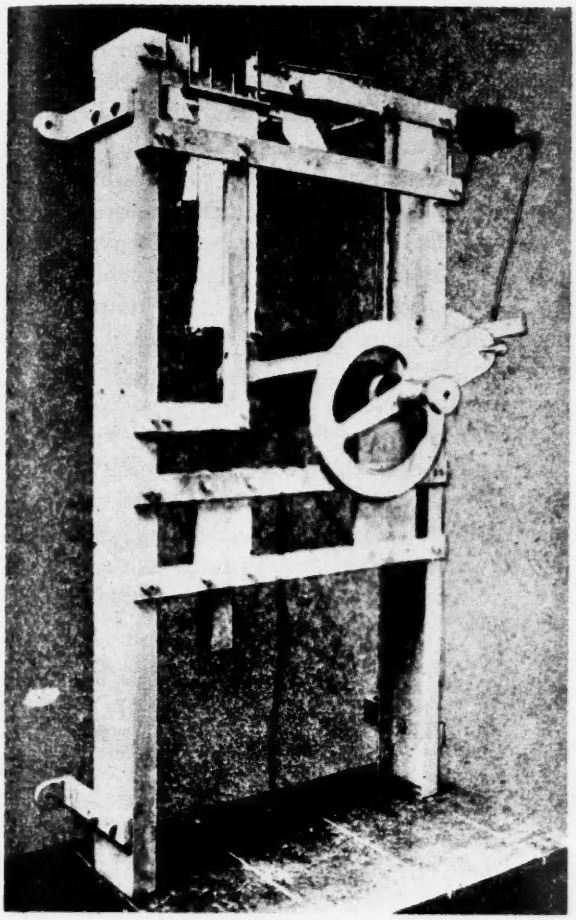


FIG. IX-2. *M.I.T. abraser.*

Laboratory D.I. = tan ϕ
(Slope to the mean)

$$= \frac{\bar{L}}{C_2} = \int_0^{C_2} \frac{f(C)dc}{C_2^2} = \frac{A/C_2}{C_2}$$

Since all laboratory D.I.'s (L.D.I.'s) are taken at 800 cycles for the M.I.T. and 1,800 cycles for the Taber, C_2 is constant and tan $\phi = A/K$. The area under the percent-loss-in-strength-versus-cycle curve is thus a direct measure of the L.D.I.

Graphs of percent loss in strength versus abrasion cycles and L.D.I.'s were prepared in order to separate the following variables:

Abrasion machines:	M.I.T. Taber
Fabrics:	Twill Sateen Herringbone twill

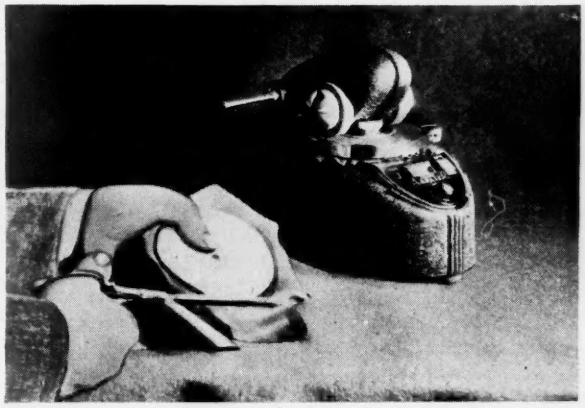


FIG. IX-3. *Taber abraser.*

Fabric surfaces:	Face Back
Abrasion directions:	Warp Filling
Tensile testing directions:	Warp Filling

It will be evident that 48 graphs were necessary to accomplish the separation of these factors.

Descriptions of the two abrasion machines and the techniques employed for determining abrasion-resistance follow:

M.I.T. Abrasion Tester (Figure IX-2)

The fabric to be tested is cut 6 × 24 inches and is inserted in the machine in such a manner as to be flexed back and forth vertically over a horizontal roller. A cam drive is applied alternately to each end of the sample to insure uniform speed of abrasion over a path 15 inches long by the width of the sample.

An aluminum bar covered on the under side with a piece of standard emery cloth rests upon the sample where it passes over the roller, and has a slight rocking motion to minimize the shock when the sample reverses direction, and to aid in clearing itself of lint. A counter records the number of abrasion cycles to which the sample is subjected. The sample is abraded unidirectionally.

For the fabrics which are the subject of this investigation, No. 240 emery cloth under a load of 535 grams was employed. The fabric was abraded at a rate of 40 cycles per minute, two specimens being abraded for each number of cycles selected. A new piece of emery cloth was used with each new sample.

Eight 6-by-1¼-inch strip tensile-strength specimens were cut from the samples so that the ensuing tensile tests were either parallel or perpendicular to the direction of abrasion. In this way, samples abraded warpwise were broken warpwise and fillingwise. Samples abraded fillingwise were also broken warpwise and fillingwise, viz.:

Abrasion direction	Test direction
Abrade warp	Test warp
Abrade filling	Test warp
Abrade filling	Test filling
Abrade warp	Test filling

The 8 tensile strength specimens thus prepared for each abrasion cycle station were raveled to 1 inch and tested according to A.S.T.M. specifications, strip method, using a pendulum-type tester, a lower jaw speed of 12 inches per minute, and a 3-inch gage length. The fabrics were abraded and tested under controlled atmospheric conditions of 65 percent relative humidity and 70°F.

Taber Abrasion Tester
(Figure IX-3)

The instrument consists of a 4-inch-diameter turntable which rotates at a constant rate in a horizontal plane. The fabric is mounted on this turntable. Above the turntable is a frame containing two rubber-emery composition wheels mounted in such a manner that they are free to rotate in a vertical plane. At the start of the test, the frame and wheels are lowered so that they rest on the turntable. The weight of the frame can be varied, and in this manner the pressure on the sample may be controlled. Various wheels of different abrasive intensity may be used. The lines of abrasion are in the form of two arcs crisscrossing each other, resulting in a circular path covering an effective area of approximately 100 cm². The turntable is driven; the wheels are not. A counter records the cycles.

Attention is called to the fact that while this instrument abrades different areas of fabric in different directions, and therefore is called a multidirectional machine, any specific point (area) is abraded in two specific directions only—one for each wheel.

Before abrading a sample, the rubber-emery wheels were dressed on S-11 emery paper for 25 cycles and subsequently dressed for 10 cycles every 500 cycles thereafter. The counter dial was reset at 0 after the first 25 dressing cycles. After each dressing of the wheels, the abrading heads were raised and the wheel faces spun lightly against a brush to remove the larger particles of rubber and emery collected on them. During the entire abrasion, a vacuum was used to remove the particles of fabric and abradant from the abraded track.

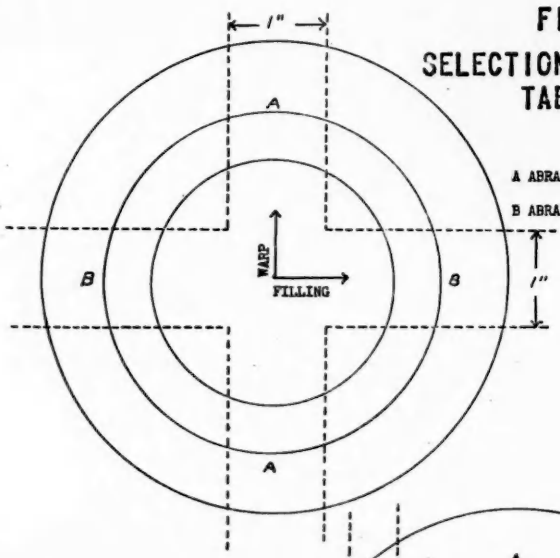


FIGURE IX-4
SELECTION OF TEST SAMPLES
TABER ABRASER

A ABRADE FILLINGWISE, TEST WARPWISE
B ABRADE WARPWISE, TEST FILLINGWISE

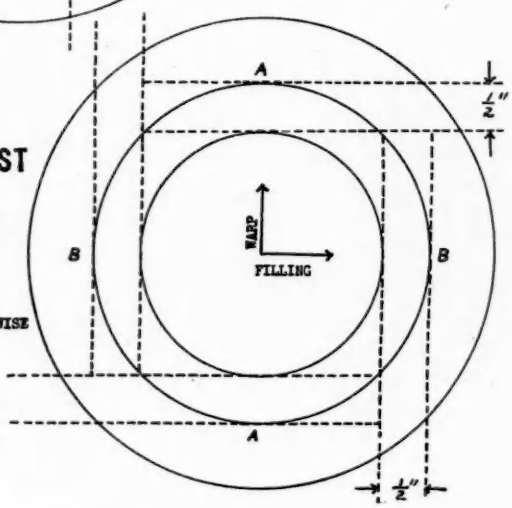


FIGURE IX-5
SELECTION OF TEST SAMPLES
TABER ABRASER

A ABRADE FILLINGWISE, TEST FILLINGWISE
B ABRADE WARPWISE, TEST WARPWISE

CS-10-grade wheels and a 500-gram headweight were used.

Five specimens of each fabric, face and back, were abraded at each cycle station. Modified A.S.T.M. strip samples were then cut from the circular abraded fabric and tensile strengths determined. In the case of specimens abraded perpendicular to the test direction, a 1-inch-wide specimen and a 1-inch gage length were used. In the case of specimens abraded parallel with the test direction, a $\frac{1}{2}$-inch-wide specimen and a 1-inch gage length were used. Figures IX-4 and IX-5, drawn to scale, make it obvious why these modified strip tensile test techniques were employed.

IX. Laboratory Abrasion Results

A. Physical Properties of Fabrics

TABLE X-1

Test		Twill	Sateen	H.B.T.
Breaking strength (strip method)	Warp	158 lbs.	143 lbs.	125 lbs.
	Filling	131 lbs.	141 lbs.	79 lbs.
% Elongation (to rupture)	Warp	13%	11%	18%
	Filling	14%	15%	16%
Ends/in.		114	112	75
Picks/in.		55	65	45
Thickness (in.)		0.018	0.019	0.023
Width (in.)		41.2	38.7	36.5
Weave		$\frac{3}{1}$	$\frac{4}{1}$ (5 harness, 2 move)	$\frac{2}{1}$ (pointed twill, 12 left 12 right, 1 at point)
Weight (oz./yd.)		8.15	8.94	9.36
Tear strength (Tongue)	Across warp	9.8 lbs.	6.2 lbs.	9.9 lbs.
	Across filling	15.5 lbs.	7.9 lbs.	8.2 lbs.
(Trapezoid)	Across warp	9.6 lbs.	11.7 lbs.	14.4 lbs.
	Across filling	9.8 lbs.	14.4 lbs.	9.5 lbs.
Yarn strength	Warp	2.1 lbs.	1.2 lbs.	1.7 lbs.
	Filling	2.2 lbs.	1.9 lbs.	1.6 lbs.
Yarn twist (Turns/in.)	Warp	16.7	16.6	15.8
	Filling	15.4	14.1	13.1

B. M.I.T. Abrasion Data and Graphs

TABLE X-M1. ABRADE WARP, TEST WARP

Fabric	Surface		Abrasion cycles 0	25	50	75	100	150	200	300	400	500	600	800
Twill	Face	Average strength	143	127	130	126	124	112	98	81	86	82	66	49
		% Loss	0	11	9	12	13	22	31	43	40	43	54	66
	Back	Average strength	143	143	143	137	118	107	107	106	99	96	84	71
		% Loss	0	0	0	4	17	25	25	26	31	33	41	50
Sateen	Face	Average strength	150	139	109	107	108	104	82	67	56	44	48	30
		% Loss	0	7	27	29	28	31	45	55	63	71	68	80
	Back	Average strength	150	154	155	114(?)	148	146	147	146	94(?)	148	144	145
		% Loss	0	0	0	24(?)	1	3	2	3	38(?)	1	4	3
H.B.T.	Face	Average strength*	128	108	106	89	86	77	68	55	49	35	36	27
		% Loss	0	16	17	30	33	40	47	57	62	73	72	79
	Back	Average strength*	111	112	110	106	101	106	96	91	80	81	74	62
		% Loss	0	0	1	5	9	5	14	18	28	27	33	44

TABLE X-M2. ABRADE FILLING, TEST WARP

Fabric	Surface		Abrasion cycles 0	25	50	75	100	150	200	300	400	500	600	800
Twill	Face	Average strength	166	96	64	50	36	30	12	8	3	1	0.3	0.2
		% Loss	0	42	61	70	78	82	93	95	98	99	100	100
	Back	Average strength	166	94	84	72	64	60	42	35	13	15	10	6
		% Loss	0	43	49	57	61	64	75	79	92	91	94	96
Sateen	Face	Average strength	159	105	76	70	58	45	36	25	10	6	5	3
		% Loss	0	34	52	56	64	72	78	85	94	96	97	98
	Back	Average strength	159	129	126	125	124	120	111	91	85	87	57	45
		% Loss	0	19	21	21	22	25	30	43	47	45	64	72
H.B.T.	Face	Average strength*	123	91	70	56	43	37	27	21	7	5	4	1
		% Loss	0	26	43	54	65	70	78	83	94	96	97	99
	Back	Average strength*	128	92	72	55	52	37	29	29	19	14	12	7
		% Loss	0	28	44	57	59	71	77	77	85	89	91	95

* The apparent discrepancy at zero cycles, face and back, is actual data on two sets of controls.

TABLE X-M3. ABRADE FILLING, TEST FILLING

Fabric	Surface		Abrasion cycles 0	25	50	75	100	150	200	300	400	500	600	800
Twill	Face	Average strength	120	121	121	121	113	118	114	104	113	110	109	113
		% Loss	0	0	0	0	6	2	5	13	6	8	9	6
	Back	Average strength	120	121	116	119	116	106	113	101	100	93	90	82
		% Loss	0	0	3	1	3	12	6	16	17	23	25	32
Sateen	Face	Average strength	118	119	126	123	123	120	111	118	125	116	118	112
		% Loss	0	0	0	0	0	2	10	4	0	2	0	5
	Back	Average strength	118	105	106	109	102	89	83	70	66	58	50	39
		% Loss	0	11	10	9	14	25	30	41	44	51	58	67
H.B.T.	Face	Average strength	75	78	71	71	72	83	76	73	84	86	86	72
		% Loss	0	0	5	5	4	0	0	3	0	0	0	4
	Back	Average strength	96	96	99	100	100	100	98	88	86	78	71	74
		% Loss	0	0	0	0	0	0	0	7	10	19	26	23

TABLE X-M4. ABRADE WARP, TEST FILLING

Fabric	Surface		Abrasion cycles 0	25	50	75	100	150	200	300	400	500	600	800
Twill	Face	Average strength	120	118	119	122	118	122	117	109	121	119	117	110
		% Loss	0	2	1	0	2	0	2	9	0	1	2	8
	Back	Average strength	120	75	73	56	57	52	45	34	32	30	27	14
		% Loss	0	38	39	53	53	57	63	72	73	75	78	88
Sateen	Face	Average strength	118	113	117	112	111	118	118	115	121	120	116	117
		% Loss	0	4	1	5	6	0	0	2	0	2	6	5
	Back	Average strength	118	81	65	58	54	44	47	36	23	18	14	5
		% Loss	0	31	45	51	54	63	60	69	81	85	88	96
H.B.T.	Face	Average strength	85	72	75	75	80	77	81	76	71	77	78	75
		% Loss	0	15	12	12	6	9	5	11	16	9	8	12
	Back	Average strength	85	72	64	56	42	39	41	30	29	26	23	17
		% Loss	0	15	25	34	51	54	52	65	66	69	73	80

C. Taber Abrasion Data and Graphs

TABLE X-T1. ABRADE WARP, TEST WARP

Fabric	Surface		Abrasion cycles 0	200	400	600	800	1,000	1,200	1,400	1,600	1,800
Twill	Face	Average strength*	71	64	44	36	30	26	17	12	11	11
		% Loss	0	9	38	49	58	63	77	83	85	84
	Back	Average strength*	71	65	48	50	45	39	34	30	29	27
		% Loss	0	8	32	29	37	46	52	58	59	62
Sateen	Face	Average strength*	77	52	31	24	20	17	14	9	10	7
		% Loss	0	32	60	69	74	78	82	89	87	91
	Back	Average strength*	77	76	71	71	68	67	64	63	60	46
		% Loss	0	1	8	8	11	12	17	18	22	40
H.B.T.	Face	Average strength*	61	52	36	27	21	13	11	9	4	5
		% Loss	0	15	41	56	65	79	83	86	94	92
	Back	Average strength*	61	48	36	31	26	19	19	15	15	12
		% Loss	0	22	42	49	57	70	70	76	75	81

* Strength is for ½-inch strip.

TABLE X-T2. ABRADE FILLING, TEST WARP

Fabric	Surface		Abrasion cycles 0	200	400	600	800	1,000	1,200	1,400	1,600	1,800
Twill	Face	Average strength	157	120	111	96	85	74	64	58	49	39
		% Loss	0	24	29	39	46	53	59	63	69	75
	Back	Average strength	157	119	114	109	93	91	82	71	74	72
		% Loss	0	24	27	31	41	42	48	55	53	54
Sateen	Face	Average strength	147	114	87	74	66	50	40	33	31	21
		% Loss	0	22	41	50	55	66	73	78	79	86
	Back	Average strength	147	147	126	119	129	127	127	130	111	123
		% Loss	0	0	14	19	12	14	14	12	24	16
H.B.T.	Face	Average strength	127	85	70	48	36	37	33	27	31	21
		% Loss	0	33	45	62	72	71	74	79	76	84
	Back	Average strength	124	118	98	87	78	57	57	53	47	43
		% Loss	0	5	21	30	37	54	54	57	62	65

TABLE X-T3. ABRADE FILLING, TEST FILLING

Fabric	Surface		Abrasion cycles 0	200	400	600	800	1,000	1,200	1,400	1,600	1,800
Twill	Face	Average strength*	58	61	60	58	60	55	58	53	57	56
		% Loss	0	0	0	1	0	5	0	8	1	3
	Back	Average strength*	58	51	42	34	31	30	26	27	22	22
		% Loss	0	12	28	41	46	48	55	54	62	62
Sateen	Face	Average strength*	62	56	52	54	53	54	57	49	51	52
		% Loss	0	10	17	13	15	12	8	22	17	16
	Back	Average strength*	62	47	34	32	26	24	23	18	20	21
		% Loss	0	24	45	48	58	61	63	71	68	66
H.B.T.	Face	Average strength*	38	41	43	42	45	41	41	36	37	39
		% Loss	0	0	0	0	0	0	0	5	2	0
	Back	Average strength*	38	38	27	25	24	17	18	18	16	13
		% Loss	0	1	29	33	35	55	52	53	59	65

* Strength is for ½-inch strip.

TABLE X-T4. ABRADE WARP, TEST FILLING

Fabric	Surface		Abrasion cycles 0	200	400	600	800	1,000	1,200	1,400	1,600	1,800
Twill	Face	Average strength	129	115	123	113	129	113	119	110	109	121
		% Loss	0	11	5	12	0	12	8	15	16	6
	Back	Average strength	129	107	93	80	71	70	62	57	54	47
		% Loss	0	17	28	38	45	46	52	56	58	64
Sateen	Face	Average strength	131	104	107	114	106	106	118	105	119	119
		% Loss	0	21	18	13	19	19	10	20	9	9
	Back	Average strength	131	112	76	57	49	44	40	37	35	29
		% Loss	0	15	42	56	63	66	69	72	73	78
H.B.T.	Face	Average strength	90	83	57	47	73	69	84	75	84	84
		% Loss	0	8	37	48	19	23	7	17	7	7
	Back	Average strength	93	85	81	65	56	55	53	51	40	38
		% Loss	0	9	12	30	40	40	43	45	57	59

X. Discussion of Laboratory Abrasion Results

Table XI-1 is a tabulation of areas under the percent-loss-in-strength-versus-cycles graphs. As shown in Section VIII, the areas are laboratory destructive indices and may be used to indicate laboratory abrasion-resistance. The lower the number, the greater is the abrasion-resistance. Since the M.I.T. area represents 800 cycles and the Taber represents 1,800 cycles, the values may be compared within each machine only, but not between machines.

Table XI-2 is a rearrangement of Table XI-1, with the samples placed in the order of their abrasion-resistance.

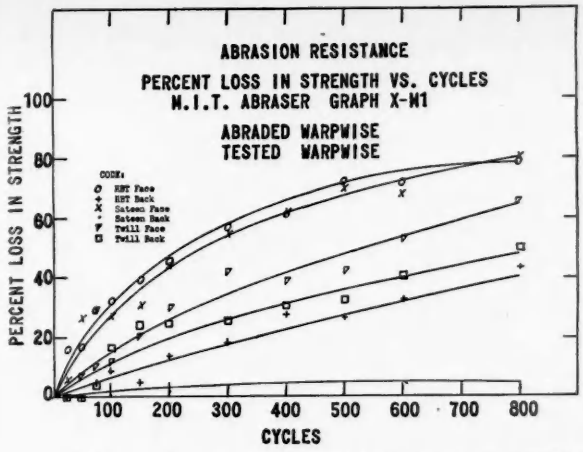
TABLE XI-1. LABORATORY DESTRUCTIVE INDICES (L.D.I.) (AREAS UNDER PERCENT-LOSS-IN-STRENGTH GRAPHS)

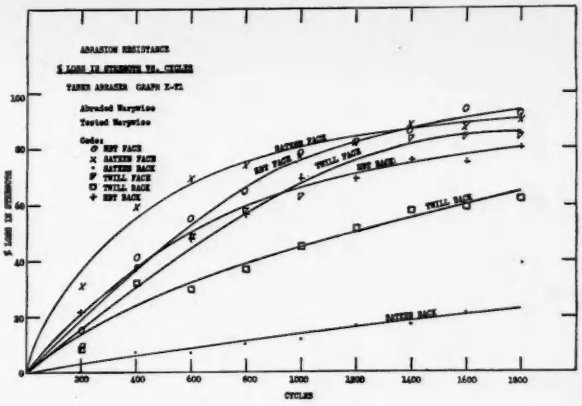
	Twill face	Twill back	Sateen face	Sateen back	H.B.T. face	H.B.T. back
Abrade warp, test warp						
M.I.T. Graph X-M1	15.50	11.75	22.36	1.20	23.62	8.97
Taber Graph X-T1	50.18	35.04	62.64	10.96	55.96	49.76
Abrade filling, test warp						
M.I.T. Graph X-M2	36.34	32.09	35.97	18.48	33.37	31.74
Taber Graph X-T2	41.72	34.60	49.84	11.86	55.44	35.00
Abrade filling, test filling						
M.I.T. Graph X-M3	2.58	6.77	0.88	17.40	0.88	4.82
Taber Graph X-T3	1.44	37.48	12.66	46.84	0.00	35.68
Abrade warp, test filling						
M.I.T. Graph X-M4	1.80	27.56	1.69	29.59	4.13	24.74
Taber Graph X-T4	8.06	37.68	12.06	49.68	12.92	30.64

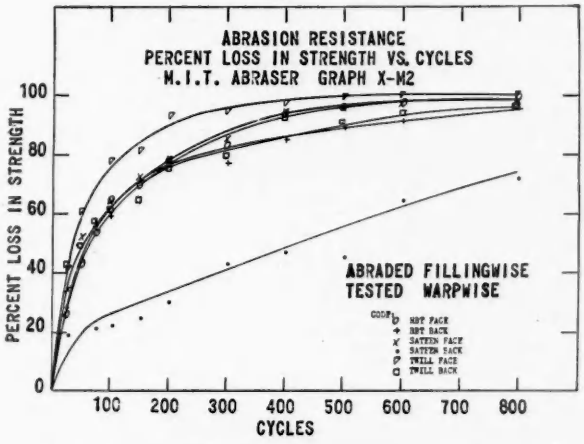
TABLE XI-2. LABORATORY D. I. RESISTANCE RANK

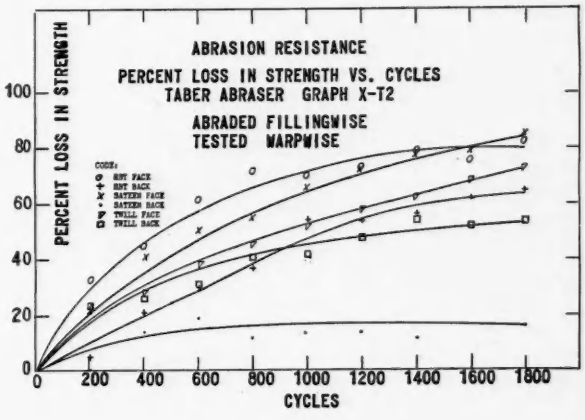
	Abrade warp Test warp M.I.T.	Abrade warp Test warp Taber	Abrade filling Test warp M.I.T.	Abrade filling Test warp Taber	Abrade filling Test filling M.I.T.	Abrade filling Test filling Taber	Abrade warp Test filling M.I.T.	Abrade warp Test filling Taber
Best	SB* 1.20	SB 10.96	SB 18.48	SB 11.86	SF 0.88	HF 0.00	SF 1.69	TF 8.06
	HB 8.97	TB 35.04	HB 31.74	TB 34.60	HF 0.88	TF 1.44	TF 1.80	SF 12.06
	TB 11.74	HB 49.76	TB 32.09	HB 35.00	TF 2.58	SF 12.66	HF 4.13	HF 12.92
	TF 15.50	TF 50.18	HF 33.37	TF 41.72	HB 4.82	HB 35.68	HB 24.74	HB 30.64
	SF 22.36	HF 55.96	SF 35.97	SF 49.84	TB 6.77	TB 37.48	TB 27.56	TB 37.68
Worst	HF 23.62	SF 62.64	TF 36.34	HF 55.44	SB 17.40	SB 46.84	SB 29.59	SB 49.68

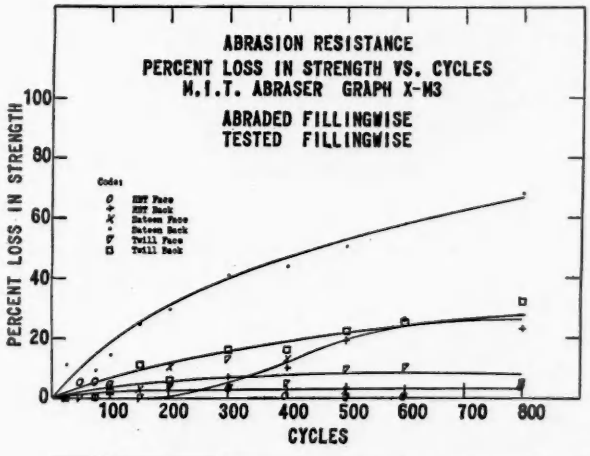
* TF—Twill face; TB—twill back; SF—sateen face; SB—sateen back; HF—H.B.T. face; HB—H.B.T. back.

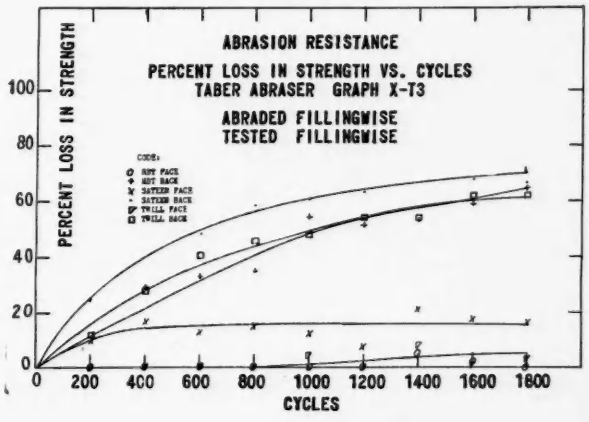

ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
M.I.T. ABRASER GRAPH X-M1
ABRADED WARPWISE
TESTED WARPWISE
PERCENT LOSS IN STRENGTH
CYCLES

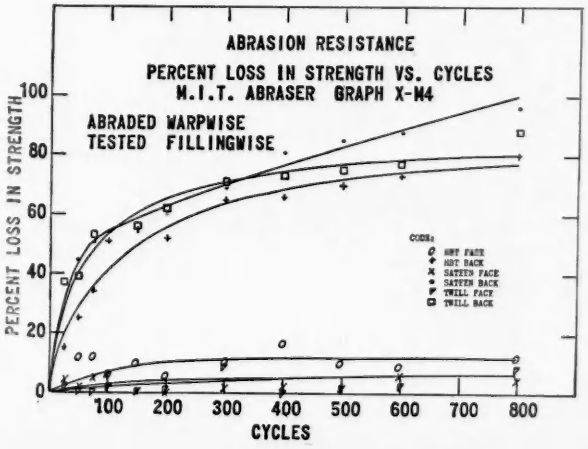

ABRASION RESISTANCE
TABER ABRASER GRAPH X-T1
CYCLES

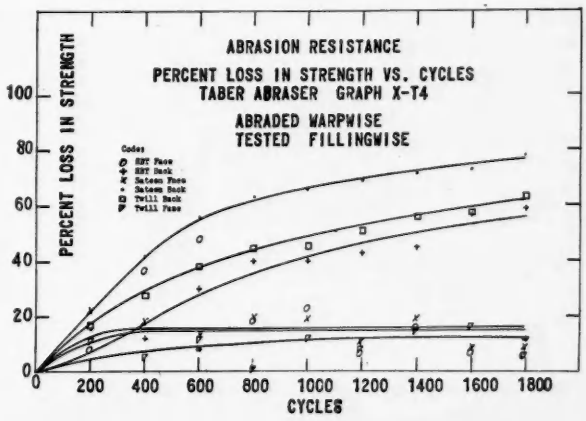

ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
M.I.T. ABRASER GRAPH X-M2
ABRADED FILLINGWISE
TESTED WARPWISE
PERCENT LOSS IN STRENGTH
CYCLES

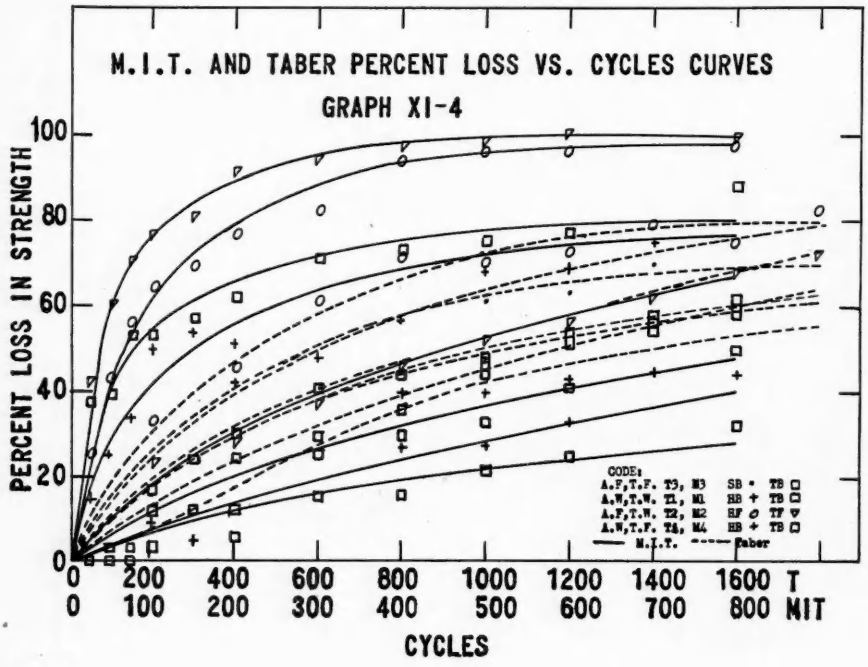

ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
TABER ABRASER GRAPH X-T2
ABRADED FILLINGWISE
TESTED WARPWISE
PERCENT LOSS IN STRENGTH
CYCLES


ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
M.I.T. ABRASER GRAPH X-M3
ABRADED FILLINGWISE
TESTED FILLINGWISE
PERCENT LOSS IN STRENGTH
CYCLES


ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
TABER ABRASER GRAPH X-T3
ABRADED FILLINGWISE
TESTED FILLINGWISE
PERCENT LOSS IN STRENGTH
CYCLES


ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
M.I.T. ABRASER GRAPH X-M4
ABRADED WARPWISE
TESTED FILLINGWISE
PERCENT LOSS IN STRENGTH
CYCLES


ABRASION RESISTANCE
PERCENT LOSS IN STRENGTH VS. CYCLES
TABER ABRASER GRAPH X-T4
ABRADED WARPWISE
TESTED FILLINGWISE
PERCENT LOSS IN STRENGTH
CYCLES



Correlation Between M.I.T. and Taber Instruments

Visual inspection shows that both the M.I.T. and Taber instruments rank each set of abrasion and test directions in substantially the same order.

Kendall rank correlation coefficients confirm good agreement between machines.

Mathematical Relationship Between M.I.T. and Taber Instruments

Graph XI-4 is a plot of both M.I.T. and Taber percent-loss-in-strength-versus-cycles curves. Visual inspection shows that all curves for both machines are of the same mathematical nature.

If percent loss is plotted against the logarithm of cycles, straight lines result, graphically indicating that the curves have the same mathematical equation.

Graph XI-5 is a representative percent-loss-in-strength-versus-log-cycle plot.

Mathematically, the Taber and M.I.T. equation is:

$$L = a \log C + b,$$

where L = % loss in strength,
C = abrasion cycles,
a and b = constants.

Because a simple logarithmic relationship exists, if M.I.T. cycles are plotted against Taber cycles at selected percent-strength-loss levels, a straight line results. (Conversely, such a plot giving a straight line in every case is additional proof that the relationship between strength and cycles is logarithmic.)

Graph XI-5A plots M.I.T. versus Taber cycles at selected percent-strength-loss levels. Straight lines always result but the slopes are not constant. This indicates that a and b in the above equation vary for the two machines, and also vary for different fabrics, different abrasion directions, and different test directions on the same machine. The constants thus reflect both machine, abrasion, and test direction, and fabric form-factor characteristics. It is obvious that, because the constants do not reflect a machine characteristic alone, no simple relationship between the M.I.T. and Taber instruments exists. One cannot state that x cycles on the M.I.T. machine are equivalent to y cycles on the Taber.

Data procured in this investigation may be used further quantitatively to relate the two machines; at the present writing this has not been accomplished.

Correlation Between Abrading in Two Directions When Testing in One Direction

Abrading warpwise or fillingwise and testing warpwise shows sateen back to be best and H.B.T.

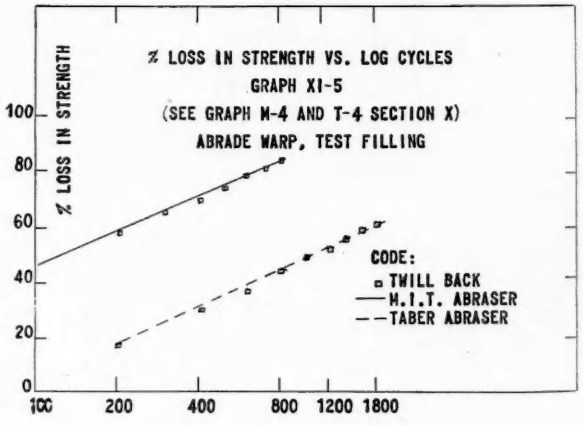


TABLE XI-3. KENDALL CORRELATION COEFFICIENTS: M.I.T. VERSUS TABER

Abrade warp, test warp

M.I.T.	SB	HB	TB	TF	SF	HF
Taber	SB	TB	HB	TF	HF	SF

Correlation coefficient $T = +0.73$

Abrade filling, test warp

M.I.T.	SB	HB	TB	HF	SF	TF
Taber	SB	TB	HB	TF	SF	HF

Correlation coefficient $T = +0.47$

Abrade filling, test filling

M.I.T.	HF	SF	TF	HB	TB	SB
Taber	HF	TF	SF	HB	TB	SB

Correlation coefficient $T = +0.87$

Abrade warp, test filling

M.I.T.	SF	TF	HF	HB	TB	SB
Taber	TF	SF	HF	HB	TB	SB

Correlation coefficient $T = +0.87$

Perfect direct correlation = + 1.00 *e.g.*, M.I.T. 1 2 3 4 5 6
Taber 1 2 3 4 5 6

Perfect inverse correlation = − 1.00 *e.g.*, M.I.T. 1 2 3 4 5 6
Taber 6 5 4 3 2 1

No correlation = 0.00 *e.g.*, M.I.T. 1 2 3 4 5 6
Taber 3 5 1 4 6 2

Critical values of T: 99% significance level $T = 0.92$
95% significance level $T = 0.81$
90% significance level $T = 0.73$

Specimen calculation:

Abrade filling, test filling

		HF	SF	TF	HB	TB	SB
Rank:	M.I.T.	1	2	3	4	5	6
	Taber	1	3	2	4	5	6

ΣK = higher numbers to right $5 + 3 + 3 + 2 + 1 + 0 = 14$

$$S = 2\Sigma K - \frac{n_1(n_2 - 1)}{2} = 2 \times 14 - \frac{6 \times 5}{2} = 28 - 15 = 13$$

$$T = \frac{2S}{n_1(n_2 - 1)} = \frac{2 \times 13}{6 \times 5} = \frac{26}{30} = +0.87 \text{ (correlation coefficient)}$$

For perfect direct correlation: M.I.T. 1 2 3 4 5 6
Taber 1 2 3 4 5 6

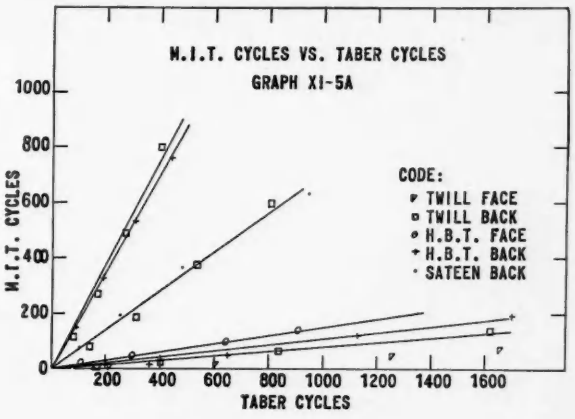
ΣK = higher numbers to right $5 + 4 + 3 + 2 + 1 = 15$

$$S = 30 - 15 = +15$$

$$T = \frac{2 \times 15}{30} = +1.00$$

back probably worst. Abrading warpwise or fillingwise and testing fillingwise shows sateen face probably to be best and sateen back worst. Table XI-6 shows that, independent of abrasion direction, the various fabric surfaces show the same L.D.I. rank when tested in a specific direction. While the ranks are the same, the extents are not.

Correlation coefficients quantitatively confirm the above observations.



Further correlation may be shown by adding laboratory destructive indices for the two abrasion and single test directions (Table XI-7).

This summation assumes equal warp and filling abrasion direction and intensity. Summing any fraction of warp or filling L.D.I.'s will not change the rank correlation, for the component parts have the same rank.

Correlation Between Testing in Two Directions When Abrading in One Direction

Comparing ranks between warp and filling tensile tests when the sample is abraded warpwise shows an inverse relationship and significant inverse rank. For example, SB abraded warpwise shows the best L.D.I. when tested warpwise, and the poorest L.D.I. when tested fillingwise.

Similarly, comparing warp and filling tests when abrading fillingwise shows the same significant in-

TABLE XI-6. KENDALL CORRELATION COEFFICIENTS (ABRADING IN TWO DIRECTIONS; TESTING IN ONE DIRECTION)

Abrade warp versus abrade filling (test warp)

M.I.T.	Abrade warp	SB	HB	TB	TF	SF	HF
	Abrade filling	SB	HB	TB	HF	SF	TF

Correlation coefficient = + 0.60

Taber	Abrade warp	SB	TB	HB	TF	HF	SF
	Abrade filling	SB	TB	HB	TF	SF	HF

Correlation coefficient = + 0.87

Abrade warp versus abrade filling (test filling)

M.I.T.	Abrade warp	SF	TF	HF	HB	TB	SB
	Abrade filling	SF	HF	TF	HB	TB	SB

Correlation coefficient = + 0.87

Taber	Abrade warp	TF	SF	HF	HB	TB	SB
	Abrade filling	HF	TF	SF	HB	TB	SB

Correlation coefficient = + 0.73

TABLE XI-7. SUM OF LABORATORY DESTRUCTIVE INDICES

Abrade warp and filling, test warp						
M.I.T.	TF	TB	SF	SB	HF	HB
Abrade warp, test warp	15.50	11.75	22.36	1.20	23.62	8.97
Abrade filling, test warp	36.34	32.09	35.97	18.48	33.37	31.74
Total	51.84	43.84	58.33	19.68	56.99	40.71
Taber						
Abrade warp, test warp	50.18	35.04	62.64	10.96	55.96	49.76
Abrade filling, test warp	41.72	34.60	49.84	11.86	55.44	35.00
Total	91.90	69.64	112.48	22.82	111.40	84.76
Abrade warp and filling, test filling						
M.I.T.	TF	TB	SF	SB	HF	HB
Abrade filling, test filling	2.58	6.77	0.88	17.40	0.88	4.82
Abrade warp, test filling	1.80	27.56	1.69	29.59	4.13	24.74
Total	4.38	34.33	2.57	46.99	5.01	29.56
Taber						
Abrade filling, test filling	1.44	37.48	12.66	46.84	0.00	35.68
Abrade warp, test filling	8.06	37.68	12.06	49.68	12.92	30.64
Total	9.50	75.16	24.72	96.52	12.92	66.32

Rank correlation:

Abrade warp and filling, test warp

M.I.T.	SB	HB	TB	TF	HF	SF
Taber	SB	TB	HB	TF	HF	SF

Correlation coefficient = + 0.87

Abrade warp and filling, test filling

M.I.T.	SF	TF	HF	HB	TB	SB
Taber	TF	HF	SF	HB	TB	SB

Correlation coefficient = + 0.74

verse relationship and correlation. Again, SB is best when tested warpwise and poorest when tested fillingwise.

To prove further that inverse correlation exists, summing the two test directions for each abrasion direction cancels any possibility of ranking fabrics (Table XI-9), because those which exhibit high abrasion-resistance warpwise show low resistance fillingwise. Therefore correlation coefficients on the sums show no significance.

Concordance Among Abrading in Two Directions and Testing in Two Directions

Tables XI-6 and XI-7 show that, in testing warpwise, fabric backs are more resistant than fabric faces, the sateen being the best. In testing fillingwise, fabric faces are more resistant. Considering all abrasion and testing directions, it is impossible to decide which fabric and surface is, overall, most abrasion-resistant. Substantively the cotton fiber (for a given grade and staple length) has a single

TABLE XI-8. KENDALL CORRELATION COEFFICIENTS (TESTING IN TWO DIRECTIONS; ABRADING IN ONE DIRECTION)

Test warp versus test filling (abrade warp)

M.I.T.	Test warp	SB	HB	TB	TF	SF	HF
	Test filling	SF	TF	HF	HB	TB	SB

Correlation coefficient = − 0.60

Taber	Test warp	SB	TB	HB	TF	HF	SF
	Test filling	TF	SF	HF	HB	TB	SB

Correlation coefficient = − 0.73

Test warp versus test filling (abrade filling)

M.I.T.	Test warp	SB	HB	TB	HF	SF	TF
	Test filling	SF	HF	TF	HB	TB	SB

Correlation coefficient = − 0.60

Taber	Test warp	SB	TB	HB	TF	SF	HF
	Test filling	HF	TF	SF	HB	TB	SB

Correlation coefficient = − 0.87

Perfect direct correlation = + 1.00
Perfect inverse correlation = − 1.00
No correlation = 0.00

TABLE XI-9. Sum of Laboratory Destructive Indices

	TF	TB	SF	SB	HF	HB
Abrade Warp, Test Warp and Filling						
M.I.T.						
Abrade warp, test warp	15.50	11.75	22.36	1.20	23.62	8.97
Abrade warp, test filling	1.80	27.56	1.69	29.59	4.13	24.74
Total	17.30	39.31	24.05	30.79	27.75	33.71
Taber						
Abrade warp, test warp	50.18	35.04	62.64	10.96	55.96	49.76
Abrade warp, test filling	8.06	37.68	12.06	49.68	12.92	30.64
Total	58.24	72.72	74.70	60.64	68.88	80.40
Abrade Filling, Test Warp and Filling						
M.I.T.						
Abrade filling, test filling	2.58	6.77	0.88	17.40	0.88	4.82
Abrade filling, test warp	36.34	32.09	35.97	18.48	33.37	31.74
Total	38.92	38.86	36.85	35.88	34.25	36.56
Taber						
Abrade filling, test filling	1.44	37.48	12.66	46.84	0.00	35.68
Abrade filling, test warp	41.72	34.60	49.84	11.86	55.44	35.00
Total	43.16	72.08	62.50	58.70	55.44	70.68

Rank correlation:

Abrade warp, test warp and filling

M.I.T.	TF	SF	HF	SB	HB	TB
Taber	TF	SB	HF	TB	SF	HB

Correlation coefficient + 0.33

Abrade filling, test warp and filling

M.I.T.	HF	SB	HB	SF	TB	TF
Taber	TF	HF	SB	SF	HB	TB

Correlation coefficient + 0.20

inherent abrasion-resistance. Since only cotton is being studied in this investigation, any differences in abrasion-resistance must come from such geometric factors as weave, twist, yarn diameter, resilience, etc. What is gained in one abrasion and test direction by proper use of these factors is lost in the other. Tables XI-8 and XI-9 bear out this inverse relationship. Table XI-10 shows that actually there is no "best" fabric if each is abraded and tested equally in each of the four directions.

Table XI-11 sums all four abrasion and test directions and shows by such a combination that no fabric ranking is possible.

Summarizing, if all abrasion and tension directions are considered simultaneously and equally, all six fabric surfaces will be equally good (or bad). Likewise, if abrasion is unidirectional and tensions are combined, no significant ranking occurs. Only when tensions are specific (abrasion directions may or may not be combined) do differences in abrasion-resistance become obvious.

The Combat Course experiment shows that differences in abrasion-resistance do exist. Equal combinations of all four abrasion and tension directions, or equal combinations of perpendicular tensions are of no value because they conceal these differences. An "over-all" abrasion-resistance combination tells nothing. Hence attention must be paid to unidirectional tension if differences are to be separated.

Obviously, on the Combat Course tensions occur in all directions; but there are specific tension and abrasion directions which predominate. These must be given the bulk of the weight in evaluating the abrasion-resistance of the garment in the laboratory. The minor abrasion and tension directions must also be included. How much weight each portion receives is the crux of the Combat Course-laboratory correlation. It will be discussed in Section XV.

XI. Photomacrographs of Fabrics

As an aid in interpreting Combat Course and laboratory abrasion results, as well as in correlating the two, photomacrographs of all fabric surfaces

TABLE XI-10. CONCORDANCE COEFFICIENT W (CONCORDANCE AMONG TWO ABRASION AND TWO TEST DIRECTIONS)

M.I.T. rank	SB	HB	TB	TF	SF	HF
Abrade warp, test warp	1	2	3	4	5	6
Abrade filling, test warp	1	2	3	6	5	4
Abrade filling, test filling	6	4	5	3	2	1
Abrade warp, test filling	6	4	5	2	1	3

Taber rank	SB	TB	HB	TF	HF	SF
Abrade warp, test warp	1	2	3	4	5	6
Abrade filling, test warp	1	2	3	4	6	5
Abrade filling, test filling	6	5	4	2	1	3
Abrade warp, test filling	6	5	4	1	3	2

Concordance coefficient W

M.I.T.	+ 0.04
Taber	+ 0.05
Perfect concordance	+ 1.00
No concordance	0.00

Speciment calculation: M.I.T.	SB	HB	TB	TF	SF	HF
Abrade warp, test warp	1	2	3	4	5	6
Abrade filling, test warp	1	2	3	6	5	4
Abrade filling, test filling	6	4	5	3	2	1
Abrade warp, test filling	6	4	5	2	1	3

$$\Sigma x = 14 + 12 + 16 + 15 + 13 + 14 = 84$$
$$\Sigma x^2 = 196 + 144 + 256 + 225 + 169 + 196 = 1186$$

$$S = \Sigma x^2 - \frac{(\Sigma x)^2}{n} = 1186 - \frac{7056}{6} = 10$$

$$W = \frac{12S}{m^2(n^3 - n)} = \frac{12 \times 10}{4^2(6^3 - 6)} = \frac{120}{3360} = .04$$

where x = an individual rank
n = number of ranks (6 columns)
m = number of comparisons (4 rows)

were made. Sections XIII and XIV will show that the extent of destruction of fabrics on the Combat Course and in the laboratory can be related to weave, percent warp and percent filling yarns on the fabric surface, length of yarn float, and (possibly) width of yarn float.

Photographs XII-1A–F show each fabric surface.

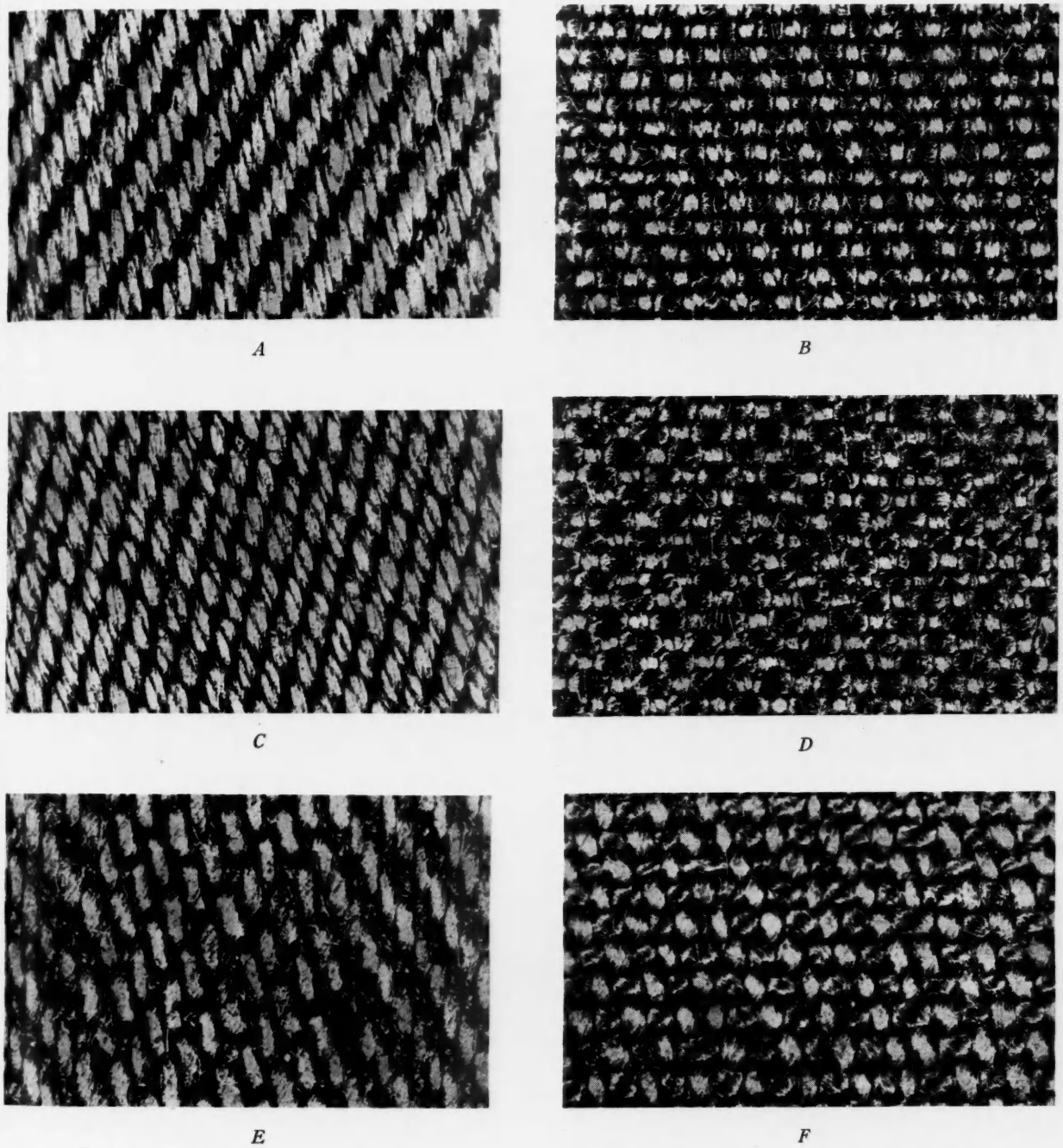
TABLE XI-11. LABORATORY DESTRUCTIVE INDICES. SUM OF TWO ABRASION AND TWO TEST DIRECTIONS

M.I.T.	TF	TB	SF	SB	HF	HB
Abrade warp, test warp	15.50	11.75	22.36	1.20	23.62	8.97
Abrade filling, test warp	36.34	32.09	35.97	18.48	33.37	31.74
Abrade filling, test filling	2.58	6.77	0.88	17.40	0.88	4.82
Abrade warp, test filling	1.80	27.56	1.69	29.59	4.13	24.74
Total	56.22	78.17	60.90	66.67	62.00	70.27
Taber						
Abrade warp, test warp	50.18	35.04	62.64	10.96	55.96	49.76
Abrade filling, test warp	41.72	34.60	49.84	11.86	55.44	35.00
Abrade filling, test filling	1.44	37.48	12.66	46.84	0.00	35.68
Abrade warp, test filling	8.06	37.68	12.06	49.68	12.92	30.64
Total	101.40	144.80	137.20	119.34	124.32	151.08

Rank correlation

M.I.T.	TF	SF	HF	SB	HB	TB
Taber	TF	SB	HF	SF	TB	HB

Correlation coefficient + 0.47



A *B*

C *D*

E *F*

Photomacrographs XII-1A-F. A—Twill face. B—Twill back. C—Sateen face. D—Sateen back. E—H.B.T. face. F—H.B.T. back.

XII. Analysis of Photomacrographs

Apparel textiles in use are subjected to various directions of abrasion and various directions of tension. Specific body motions produce specific directions of abrasion and tension. For example, the lining in men's jackets wears out under the arms because the swinging and moving of the arms essentially unidirectionally abrades the lining transverse to the warp, assuming that the lining is inserted so that the warp yarns run in the conventional vertical direction. Tension for the most part is applied longitudinally with the filling. Hence in

TABLE XII-2.

Percent of warp and filling Surfaces*

		Warp	Filling
Twill	Face	62	38
	Back	40	60
Sateen	Face	67	33
	Back	35	65
H.B.T.	Face	63	37
	Back	44	56

Length of floats† (in millimeters)

		Warp	Filling
Twill	Face	0.95	—‡
	Back	0.26	0.53
Sateen	Face	0.74	—‡
	Back	0.26	0.74
H.B.T.	Face	0.90	0.26
	Back	0.53	0.58

Width of floats† (in millimeters)

		Warp	Filling
Twill	Face	0.21	—‡
	Back	0.26	0.37
Sateen	Face	0.21	—‡
	Back	0.32	0.47
H.B.T.	Face	0.32	—‡
	Back	0.42	0.42

* Averages on the basis of 50 measurements.
† Averages on the basis of 10 measurements.
‡ Not discernible from photographs.

studying the abrasion-resistance of such a fabric specific attention must be given to abrading the fabric fillingwise (across the warp) and tensioning it fillingwise.

Thus in analyzing its abrasion-resistance, the end-use to which a garment is to be put, and the direction in which the fabric is placed in the garment, must be considered. The abrasion properties of the fabric may then be determined for the specific abrasion and tensioning directions involved. Obviously one cannot consider only one abrasion and one tension direction to the total exclusion of all others. Proper weight must be given to other directions as well.

Consider the photomacrographs as they might qualitatively be related to unidirectional abrasion and tension on the Combat Course and in the laboratory.

As the soldier traverses the Combat Course, his motion is always forward. The greatest portion of the abrasive action occurs longitudinally with the man. Most of the tensions also are applied longitudinally. All the garments used in this investigation were made with the warp yarns vertical. Hence it would appear that the best fabric would be that which had the greatest warp strength after being abraded warpwise.

The three fabrics tested on the Combat Course were the twill and H.B.T. face and the sateen back.

TABLE XIII-1. ABRASION-RESISTANCE PREDICTION

Abrade warp, test warp

	(1)		(2)		(3)	
Fabric surface	% Warp surface	Rank	Warp length	Rank	Over-all predicted rank	
TF	62	4	0.95 mm.	5	Best	SB
TB	40	2	0.26	1		TB
SF	67	6	0.74	3		HB
SB	35	1	0.26	1		HF
HF	63	5	0.90	4		TF
HB	44	3	0.53	2	Worst	SF

Abrade filling, test warp

	(1)		(2)		(3)	
Fabric surface	% Warp surface	Rank	Warp length	Rank	Over-all predicted rank	
TF	62	4	0.95 mm.	5	Best	SB
TB	40	2	0.26	1		TB
SF	67	6	0.74	3		HB
SB	35	1	0.26	1		HF
HF	63	5	0.90	4		TF
HB	44	3	0.53	2	Worst	SF

Abrade filling, test filling

	(1)		(2)		(3)	
Fabric surface	% Filling surface	Rank	Filling length	Rank	Over-all predicted rank	
TF	38	3			Best	SF
TB	60	5	0.53 mm.	2		HF
SF	33	1				TF
SB	65	6	0.74	4		HB
HF	37	2	0.26	1		TB
HB	56	4	0.58	3	Worst	SB

Abrade warp, test filling

	(1)		(2)		(3)	
Fabric surface	% Filling surface	Rank	Filling length	Rank	Over-all predicted rank	
TF	38	3			Best	SF
TB	60	5	0.53 mm.	2		HF
SF	33	1				TF
SB	65	6	0.74	4		HB
HF	37	2	0.26	1		TB
HB	56	4	0.58	3	Worst	SB

TABLE XIV-1. ABRASION-RESISTANCE RANK

	Photographic prediction	M.I.T. results	Taber results
Abrade warp, test warp			
Best	SB	SB	SB
	TB	HB	TB
	HB	TB	HB
	HF	TF	TF
	TF	SF	HF
Worst	SF	HF	SF
Abrade filling, test warp			
Best	SB	SB	SB
	TB	HB	TB
	HB	TB	HB
	HF	HF	TF
	TF	SF	SF
Worst	SF	TF	HF
Abrade filling, test filling			
Best	SF	SF	HF
	HF	HF	TF
	TF	TF	SF
	HB	HB	HB
	TB	TB	TB
Worst	SB	SB	SB
Abrade warp, test filling			
Best	SF	SF	TF
	HF	TF	SF
	TF	HF	HF
	HB	HB	HB
	TB	TB	TB
Worst	SB	SB	SB

TABLE XIV-2. CONCORDANCE COEFFICIENT BETWEEN PREDICTED, M.I.T., AND TABER ABRASION-RESISTANCE

	Concordance coefficient W
Abrade warp, test warp	0.91
Abrade filling, test warp	0.87
Abrade filling, test filling	0.92
Abrade warp, test filling	0.94
(Perfect concordance)	1.00
(No concordance)	0.00

The twill face is a warp-flush fabric (Figure XII-1A). Abrading it warpwise and tensioning it warpwise would result in pronounced damage, low strength, and poor abrasion-resistance.

The H.B.T. face is also a warp-flush fabric. Abrading and tensioning it warpwise would also result in warp yarn damage, low strength, and poor abrasion-resistance.

The sateen back is a filling-flush fabric. The warp yarns are buried and thus protected. If this fabric were abraded and tensioned warpwise, the warp yarns would not appreciably be damaged. Its warp strength would remain high and it would have good abrasion-resistance. The question might be raised that the sateen back is a filling-flush fabric, and while the warp yarns would not be abraded, the filling yarns would be; therefore the fabric would be destroyed just as quickly. The filling yarns (abraded transverse to their axis) *would* be damaged, but, since the tension is predominantly warpwise, the filling yarns would not be called upon to withstand excessive tensions. The fabric would not fail and the abrasion-resistance would remain high. Abrading the twill and H.B.T. faces fillingwise and tensioning them warpwise would cause even greater deterioration than abrading warp and tensioning warp.

Summarizing, from the nature of the Combat Course, qualitatively one would expect that of the three surfaces tested the sateen-back fabric would have the highest abrasion-resistance. Since the other two surfaces are substantially alike, in order to choose the better, the percent surface and length and width of float must be considered. Sixty-two percent of the twill face and 63 percent of the H.B.T. face is warp, an insignificant difference. The twill warp float is 0.95 mm. long; the H.B.T. is 0.90 mm. It would seem logical that, within limits, the longer the float the greater the possible damage due to abrasion. (If the float becomes so short that the yarn is sharply bent and knuckles develop, then the abrasion-resistance obviously diminishes.) The effect of the width of the float upon abrasion-resistance is not known. It would appear to be related to the float length and to the rigidity of the yarn as it lies in the fabric. A long and wide float might be just as abrasion-resistant as a short, narrow one. If such is the case then the H.B.T. might be slightly better.

Yarn and fabric rigidity, twist, sett, yarn diameter, and resilience all have an effect upon abrasion-resistance. These criteria as well as those already mentioned and analyzed collectively may be considered to be fabric geometry or form factor. The effect of form factor upon abrasion-resistance is extremely complex. This investigation has made a step toward its solution by determining the effect of weave, percent surface, and possibly float length and width. Further intensive study on form factor is necessary.

Photographic analysis of the six fabric surfaces studied in the laboratory results in the table of

predicted abrasion-resistance ranks (Table XIII-1). Part 1 of the table ranks the fabrics on a percent-surface basis. Part 2 ranks the fabrics on a float-length basis. Part 3 is the over-all predicted rank.

From the photographs, it would appear that, independent of the abrasion direction, when the tension is warpwise the fabric backs are most resistant, the sateen back being best. When the tension is fillingwise the fabric faces are most resistant, the sateen face again being best.

Section XIII shows that these photomacrographic predictions are in excellent correlation with the actual abrasion-resistance as determined in the laboratory and discussed in Section X.

XIII. Correlation Between Laboratory Abrasion Results and Photomacrographs

Table XIV-1 tabulates the photographic predictions of Section XII with laboratory abrasion results of Section X.

Visual inspection and concordance tests show that laboratory abrasion-resistance can be determined qualitatively from photomacrographs if certain precautions are taken. In this investigation all fabrics were cottons of substantially the same weight, thickness, and yarn size. Hence the photographs could be used to separate visual differences in weave, percent surface, and float length. Photomacrographs cannot distinguish differences in abrasion-resistance of different fibers or distinguish between different fabric weights and thicknesses. Hence if these latter parameters are not constant the photographs are useless. For example, the H.B.T. could be twice as heavy and twice as thick and still show the same surface in the photograph. The thicker, heavier fabric would have better abrasion-resistance but the photograph would not show it. Care must be taken in using photographs, but they can be extremely useful.

If the laboratory destructive indices are studied and compared with the photomacrographs, it will be quite clear in each case why the abrasion-resistances in the various abrasion and test directions are what they are. (Section XII introduced this analysis; it is continued here.) The twill face may be taken as a representative case. In the photograph, the warp yarns run vertical and are flush. Abrading warpwise and tensioning warpwise would cause serious damage; the abrasion-resistance would be poor. Abrading fillingwise and tensioning warpwise cuts even more warp yarns because the abrasion is transverse to the yarn axis. The abrasion-resistance would be even worse than in the former case. The filling yarns are buried in the fabric and are therefore protected. Abrading filling and testing filling would do little harm because the abradant does not touch the yarn. Abrading warpwise and testing fillingwise offers high resistance but because any filling yarns that are cut are cut transverse, the abrasion-resistance would be less than the filling abrasion. Recapitulating, one would expect that on the twill face, abrade filling-test filling would be best; abrade warp-test filling slightly worse, but still good; abrade warp-test warp, poor; abrade filling-test warp, extremely poor. The laboratory results are:

	M.I.T.	Taber
Abrade filling, test filling	2.58	1.42
Abrade warp, test filling	1.80	8.06
Abrade warp, test warp	15.50	50.18
Abrade filling, test warp	36.34	41.72

XIV. Correlation Between Combat Course Results and Photomacrographs

Results of the Combat Course experiment (Section VII) show that (1) the sateen back wears out slowest and is therefore best; (2) the H.B.T. face wears out 1.8 faster than the sateen back and is next best; (3) the twill face wears out 2.1 times faster than the sateen and is worst; (4) the twill probably wears out slightly faster than the H.B.T. The difference between them is small compared with differences between twill and sateen, and H.B.T. and sateen.

In Section XII it was stated that since the motion of the man on the Combat Course is always forward, most of the abrasion and tension directions are probably longitudinal with the man. Therefore, that fabric would be most abrasion-resistant which had the greatest warp strength after warpwise abrasion. Because the sateen back had its warp yarns buried whereas the twill and H.B.T. faces were warp-flush, from the photographs it was qualitatively predicted that the sateen back would exhibit the greatest abrasion-resistance and that there would be little difference between the twill and H.B.T., the H.B.T. probably being slightly better.

Almost perfect qualitative agreement exists between the photomacrographic predictions and the Combat Course experimental results. The photographic predictions were based on the premise that

TABLE XVI-1 (Part A). Laboratory Destructive Index Ratios

Abrade warp, test warp	M.I.T.	Taber
$\frac{TF}{SB}$ =	$\frac{15.50}{1.20} = 12.9$	$\frac{50.18}{10.96} = 4.6$
$\frac{HF}{SB}$ =	$\frac{23.62}{1.20} = 19.7$	$\frac{55.96}{10.96} = 5.1$
$\frac{TF}{HF}$ =	$\frac{15.50}{23.62} = 0.7$	$\frac{50.18}{55.96} = 0.9$

TABLE XVI-1 (Part B). Laboratory Destructive Index Ratios

Abrade filling, test warp	M.I.T.	Taber
$\frac{TF}{SB}$ =	$\frac{36.34}{18.48} = 1.97$	$\frac{41.72}{11.86} = 3.52$
$\frac{HF}{SB}$ =	$\frac{33.37}{18.48} = 1.81$	$\frac{55.44}{11.86} = 4.67$
$\frac{TF}{HF}$ =	$\frac{36.34}{33.37} = 1.09$	$\frac{41.72}{55.44} = 0.75$
Abrade filling, test filling		
$\frac{TF}{SB}$ =	$\frac{2.58}{17.40} = 0.15$	$\frac{1.44}{46.84} = 0.03$
$\frac{HF}{SB}$ =	$\frac{0.88}{17.40} = 0.05$	$\frac{0.00}{46.84} = 0.00$
$\frac{TF}{HF}$ =	$\frac{2.58}{0.88} = 2.93$	$\frac{1.44}{0.00} = \infty$
Abrade warp, test filling		
$\frac{TF}{SB}$ =	$\frac{1.80}{29.59} = 0.06$	$\frac{8.06}{49.68} = 0.16$
$\frac{HF}{SB}$ =	$\frac{4.13}{29.59} = 0.14$	$\frac{12.92}{49.68} = 0.26$
$\frac{TF}{HF}$ =	$\frac{1.80}{4.13} = 0.44$	$\frac{8.06}{12.92} = 0.62$

the dominant tension direction was warpwise regardless of abrasion direction. Since the Combat Course results correlate with the warpwise tension analysis, the premise that the greatest portion of tensions developed on the Combat Course are truly longitudinal (warpwise) with the man is a reasonable assumption. (Again it may be pointed out that these garments were all made with the warp yarns running longitudinally.) Had the tensions been predominantly fillingwise, the Combat Course results never could have ranked the sateen back best.

If the magnitudes and directions of abrasion and tensions under Combat Course conditions are known, photomacrographs can be used qualitatively to rank abrasion-resistance. However, the limitations of the photographs must be thoroughly understood. (See Section XIII.)

XV. Correlation Between Laboratory Abrasion and Combat Course Results

Quantitatively, the three fabrics tested on the Combat Course have destructive indices related to each other as follows:

Sateen back : H.B.T. face : twill face = 1 : 1.8 : 2.1

For perfect correlation, laboratory abrasion tests must also show these fabrics to have the same quantitative relationship.

On the Combat Course, the predominant abrasion and tension direction is warpwise. But there must be some filling abrasion and warp tension, some filling abrasion and filling tension, and some warp abrasion and filling tension. Each contributes an amount such that the resulting destructive indices have the above ratios. In the laboratory, L.D.I.'s were measured for four different abrasion and test directions. These individual L.D.I.'s must be weighted and combined in such a manner as to give ratios equivalent to those determined on the Combat Course.

Assuming that the abrasion and tension direction on the Combat Course is exclusively warpwise, the ratios of sateen to twill to H.B.T. are given in Table XVI-1 (Part A).

These ratios for $\frac{TF}{SB}$ and $\frac{HF}{SB}$ are much too high to correlate with the Combat Course results. Therefore it is evident that abrasion and tension directions on the Combat Course cannot exclusively be warpwise. Other directions must contribute to reduce these ratios.

Ratios for the other three abrasion and test directions are given in Table XVI-1 (Part B).

Abrading fillingwise and testing warpwise gives almost perfect correlation for the M.I.T., but high values for the Taber. However, from the very nature of the Combat Course and because such an abrasion and test direction to the exclusion of all others is illogical, it alone cannot be accepted.

Abrading warpwise or fillingwise and testing fillingwise ranks the fabrics inversely, and properly so. To arrive at proper ratios, empirically selected percentages of the various laboratory abrasion and

TABLE XVI-2. WEIGHTED LABORATORY DESTRUCTIVE INDICES

M.I.T.	TF	TB	SF	SB	HF	HB
A.W., T.W.* 60%	9.30	7.05	13.42	0.72	14.17	5.38
A.F., T.W. 10%	3.63	3.21	3.60	1.85	3.34	3.17
A.F., T.F. 20%	0.52	1.35	0.18	3.48	0.18	0.96
A.W., T.F. 10%	0.18	2.76	0.17	2.96	0.41	2.47
	13.63	14.37	17.37	9.01	18.10	11.98
Taber						
A.W., T.W. 60%	30.11	21.02	37.58	6.58	37.58	29.86
A.F., T.W. 10%	4.17	3.46	4.98	1.19	5.54	3.50
A.F., T.F. 20%	0.29	7.50	2.53	9.37	0.00	7.14
A.W., T.F. 10%	0.81	3.71	1.21	4.97	1.29	3.06
	35.38	35.75	46.30	22.11	44.41	43.56

	M.I.T.	Taber
$\frac{TF}{SB}$ =	$\frac{13.63}{9.01} = 1.51$	$\frac{35.38}{22.11} = 1.60$
$\frac{HF}{SB}$ =	$\frac{18.10}{9.01} = 2.01$	$\frac{44.41}{22.11} = 2.01$
$\frac{TF}{HF}$ =	$\frac{13.63}{18.10} = 0.75$	$\frac{35.38}{44.41} = 0.80$

	Best	Worst
Rank: M.I.T.:	(SB), HB, (TF), TB, SF, (HF)	
Taber:	(SB), (TF), TB, HB, (HF), SF	

* Abbreviations stand for "abrade warp, test filling," etc.

TABLE XVI-3. WEIGHTED LABORATORY DESTRUCTIVE INDICES

M.I.T.	TF	TB	SF	SB	HF	HB
A.W., T.W. 70%	10.85	8.23	15.65	0.84	16.53	6.28
A.F., T.W. 5%	1.82	1.60	1.80	0.92	1.67	1.59
A.F., T.F. 20%	0.52	1.35	0.18	3.48	0.18	0.96
A.W., T.F. 5%	0.09	1.38	0.08	1.48	0.21	1.24
	13.28	12.56	17.71	6.72	18.59	10.07
Taber						
A.W., T.W. 70%	35.13	24.53	43.85	7.67	39.17	34.83
A.F., T.W. 5%	2.09	1.73	2.49	0.59	2.77	1.75
A.F., T.F. 20%	0.29	7.50	2.53	9.37	0.00	7.14
A.W., T.F. 5%	0.40	1.88	0.60	2.48	0.65	1.53
	37.91	35.64	49.47	20.11	42.59	45.25

	M.I.T.	Taber
$\frac{TF}{SB}$ =	$\frac{13.28}{6.72} = 1.98$	$\frac{37.91}{20.11} = 1.89$
$\frac{HF}{SB}$ =	$\frac{18.59}{6.72} = 2.77$	$\frac{42.59}{20.11} = 2.12$
$\frac{TF}{HF}$ =	$\frac{13.28}{18.59} = 0.71$	$\frac{37.91}{42.59} = 0.89$

	Best	Worst
Rank: M.I.T.:	(SB), HB, TB, (TF), SF, (HF)	
Taber:	(SB), TB, (TF), (HF), HB, SF	

test directions must be combined to form a weighted laboratory D.I. These empirical percentages cannot be blindly selected; they must be logical combinations. But until the precise magnitude and direction of warp and filling abrasion, and the precise magnitude and direction of warp and filling tensions occurring on the Combat Course are known, the percentages must remain empirical.

As a first approximation, one may consider the following percentages of abrasion and tension directions to exist:

Abrade warp, test warp	60%
Abrade filling, test warp	10%
Abrade filling, test filling	20%
Abrade warp, test filling	10%

Such a combination results in the weighted L.D.I.'s shown in Table XVI-2.

Fabrics in parenthesis are those tested on the Combat Course. Qualitatively the weighting ranks the sateen properly but the twill and H.B.T. possibly are reversed, compared with the Combat Course results. Quantitatively the ratios seem low and it would appear that the abrade warp-test warp values should be increased.

By experimentation, it has been found that one set of weighting percentages which is in fair agreement with the Combat Course ratios is:

Abrade warp, test warp	70%
Abrade filling, test warp	5%
Abrade filling, test filling	20%
Abrade warp, test filling	5%

This combination is not to be construed as the only one for which the data can be given. With the present knowledge of Combat Course abrasion and tension directions no absolute and definite combination can be calculated. The above weighting factors are logical from a knowledge of the Combat Course. Use of them bears out the Combat Course results to a fair degree of accuracy, as is shown in Table XVI-3.

For both the M.I.T. and Taber, the sateen back is best. The M.I.T. shows the twill face to be much better than the H.B.T. face; the Taber shows it to be slightly better. It will readily be seen that consistently both on the Combat Course and in the laboratory, the sateen back exhibits the best abrasion-resistance. The Combat Course shows the H.B.T. to be slightly better than the twill, particularly for mild, and medium wear. The laboratory

TABLE XVI-4. WEIGHTED LABORATORY DESTRUCTIVE INDICES

M.I.T.	TF	TB	SF	SB	HF	HB
A.F., T.F. 70%	1.81	4.74	0.62	12.18	0.62	3.37
A.W., T.F. 5%	0.09	1.38	0.08	1.48	0.21	1.24
A.W., T.W. 20%	3.10	2.35	4.47	0.24	4.72	1.79
A.F., T.W. 5%	1.82	1.60	1.80	0.92	1.67	1.59
	6.82	10.07	6.97	14.82	7.22	7.99
Taber						
A.F., T.F. 70%	1.01	26.24	8.86	32.79	0.00	24.98
A.W., T.F. 5%	0.40	1.88	0.60	2.48	0.65	1.53
A.W., T.W. 20%	10.04	7.01	12.53	2.19	11.19	9.95
A.F., T.W. 5%	2.09	1.73	2.49	0.59	2.77	1.75
	13.54	36.86	24.48	38.05	14.61	38.21

Rank: M.I.T.: TF, SF, HF, HB, TB, SB
Taber: TF, HF, SF, TB, SB, HB

shows the twill to be slightly better. Here an anomaly exists, for if, as a result of the laboratory test, a choice between twill face and H.B.T. face were required, the twill should be chosen. The differences between the two are small, however.

Where the laboratory tests show large differences in abrasion-resistance, the results will be borne out on the Combat Course. If small differences are detected in the laboratory, they will not be found on the Combat Course. The laboratory tests give a more sensitive measure and can separate smaller differences than can the Combat Course tests.

Recommendations Concerning Abrasion-Resistance When Warp Yarns Run Longitudinally in the Garment

Table XVI-3 shows weighted L.D.I.'s for all other fabric surfaces in addition to the sateen back, twill face, and H.B.T. face. It can now be determined whether any other fabric surface would have shown better Combat Course resistance than the sateen back, and whether it would have been better to use the twill back and H.B.T. back in preference to the faces.

The sateen back is the best possible choice if the garment is constructed with the warp yarns running longitudinally. There is little difference between the twill face and back. However, to gain every possible advantage, it would be better to use the twill back. The H.B.T. back is preferable to the H.B.T. face in spite of the fact that the Taber H.B.T.-face value is lower than the H.B.T.-back value (Table XVI-3). The reason for this is that there is an apparent anomalous condition in the abrade filling-test filling Taber H.B.T.-face test, for the L.D.I. is zero, thus lowering the weighted L.D.I.

Recommendations Concerning Abrasion-Resistance When Filling Yarns Run Longitudinally in the Garment

If the garments are constructed with the filling yarns longitudinal with the garment, the weighted L.D.I.'s are calculated with the filling yarns receiving the bulk of the weighting:

Abrade filling, test filling	70%
Abrade warp, test filling	5%
Abrade warp, test warp	20%
Abrade filling, test warp	5%

Construction of the garments with filling yarns running longitudinally shows that fabric faces are better than the fabric backs, the twill face is best of all. Where the sateen back was best warpwise, it is substantially worst fillingwise.

Comparison of Tables XVI-3 and XVI-4 enables selection of the best abrasion-resisting fabric surface. A twill-face garment with filling yarns running lengthwise is recommended as being best under Combat Course conditions. The sateen back with its warp yarns running lengthwise is a close second. There is so little difference between these choices that they never could be distinguished on the Combat Course.

ABSTRACTS

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A list of periodicals, the abbreviations used in references to articles, and the addresses of publishers of English language publications is given on page 84 of the February, 1946, issue.

ANALYSIS: TESTING: LABORATORY METHODS

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Cellulose Analysis

Recrystallization of amorphous cellulose. P. H. Hermans and A. Weidinger. *J. Am. Chem. Soc.* **68**, 1138 (June 1946); cf. *B.I.P.C.* **16**, 385 (through *Bull. Inst. Paper Chem.* **16**, 493 (July 1946)).

Treating very dry cellulose in an efficient grinding device, such as a vibrating ball mill, yields a powder, whose x-ray diffraction pattern reveals that all 3-dimensional lattice order has disappeared. Upon wetting the powder with hot water, a recrystallization occurs, the crystalline diffraction pattern being invariably that of cellulose hydrate (cellulose *II*), whether native or regenerated fibers are used as starting material. The same results were obtained with ramie, wood pulp, and viscose rayon. The degree of crystallization has been computed in 3 ways, by estimating the percentage of the amorphous substance in the recrystallized powder from the photometrically determined ratio of the background intensities, and by employing the integral heats of wetting or the sorption isotherms of the very dry amorphous and recrystallized powders. The average value for the 3 methods is 67%. The x-ray method seems the more general procedure for estimating the amorphous portion in cellulose.

Text. Research J. Oct. 1946

Analysis of Fabrics

The quantitative analysis of fabrics made from a mixture of staple rayon and cottonized bast fiber, with emphasis on a new modification of the Schwertassek method. Franz Kocevar and Heinz Horak. *Melliand Textilber.* **25**, 296–8 (1944) (through *Chem. Abstr.* **40**, 4889[7] (Aug. 20, 1946)).

Various published physical and chemical methods of separation are evaluated critically. The modified Schwertassek method (*C.A.* **34**, 1171[2]) is as follows: Slightly overdry the textile and subject to air of constant relative humidity. Weigh the sample, boil it 10 min. in approximately 50 cc. of 1% Na_2CO_3 solution, rinse well, dry, and determine the loss of weight due to boiling. To the thus pretreated textile add about 5–10 cc. of 10% NaOH (temperature 18°), work well with a flattened glass rod, and after 30 min. roll it with a rubber-coated roller at a slight pressure on an iron-wire sieve of 400 meshes per sq. cm. on top of a fluted glass plate. Repeat twice, except that the NaOH solution is allowed to act only 1 min. instead of 30 min. After the last treatment, roll with the gradual addition of water, rinse, transfer to a filter cloth, acidify with dilute AcOH, rinse, dry, place in an air-conditioned space, and weigh. This treatment removes all the staple rayon. In the calculation of the results it is necessary to consider not only the weight losses but also a correction factor for the substances which are dissolved by the alkali, such as pectins, hemicellulose, and other ingredients of the cottonized-bast constituent.

Text. Research J. Oct. 1946

Detergency Test

Detergency—a simple method of estimation. E. Kornreich. *Textile Mfr.* **72**, 271–2 (1946) (through *Chem. Abstr.* **40**, 4541[5] (Aug. 10, 1946)).

A rapid extractive method described gives results comparable to those of methods in which are used instruments for observing degree of whiteness produced.

Text. Research J. Oct. 1946

Evaluation of Flammability

Evaluation of fabrics as to their flammability. New York Section A.A.T.C.C. *Am. Dyestuf Reptr.* **35**, P20–5 (Jan. 14, 1946).

The need for a standardized flammability test and some of the difficulties involved in devising such a test are discussed. Conditioning of the sample and preparation of the sample surface are shown to be especially important. Wool, silk, nylon, vinyon, and velon fabrics offer no flammability hazard. Cot-

ton is just as flammable as regenerated-type rayon under identical construction and testing conditions. Certain fabrics (notably pyroxylin-coated), although generally slow to ignite, burn with a violent flame difficult to extinguish, and therefore offer a definite hazard. Operating instructions and test procedure for the newly designed flammability testing apparatus as well as a proposed tentative method for testing flammability of consumer textiles are presented. Close correlation of results, using this apparatus and procedure, in a number of laboratories is said to have been obtained. K. S. Campbell

Text. Research J. Oct. 1946

Detection of Magnesium

Organic dyes as aids in textile chemical analysis. A new method of detecting magnesium with azo dyes. H. Rath and A. Sanchez. *Melliand Textilber.* **25**, 355–6 (1944) (through *Chem. Abstr.* **40**, 4885[4] (Aug. 20, 1946)).

Naphthazon 1 and Naphthazon 2 manufactured by Chemische Fabrik E. Merck, Darmstadt, are suitable for detection of Mg. Both dyes produce reddish-violet aqueous or alcoholic solutions, which turn bluish-violet after the addition of NaOH, and from which $Mg(OH)_2$ adsorbs the dye, becoming blue. At low Mg concentrations the color of the solution changes from violet to blue; at higher concentrations of Mg there is formed a precipitate of $Mg(OH)_2$ colored blue by adsorption of the dye. Naphthazon 1 gives a lavender blue, Naphthazon 2, a turquoise blue. Ca, Sr, Ba, Al, Sn, Pb, etc., do not interfere. These dyes are suitable for detecting small quantities of Mg in small textile samples. The dyes can be used to determine the natural Mg content of crude fibers in a small amount of ash. Mg salts from sizes, finishing procedures, etc., can be detected in the ash or in extracts.

Text. Research J. Oct. 1946

Determination of Equilibrium Moisture Content

Determining the moisture equilibrium curves of hygroscopic materials. Willmer A. Wink. *Ind. Eng. Chem., Anal. Ed.* **18**, 251–2 (Apr. 1946).

Samples are suspended in a crystallizing dish with a ground glass cover in which the relative humidity is controlled by saturated salt solutions. A 93-by-18-mm. Petri dish is used to hold the specimen. The Petri dish is supported by an aluminum bracket and rod which passes through the ground glass cover and is suspended from one arm of an analytical balance. By using various saturated salt solutions, complete adsorption and desorption curves can be obtained. Crystals of the solid salt should always be present and when desorption curves are being determined, sufficient crystals should be used so that they appear above the surface of the solution. A table taken from Report 40, American Paper and Pulp Association (Feb. 15, 1945), gives the equilibrium relative humidities for the saturated solutions of 17 different salts at 73°, 86°, 100°F. They range from lithium chloride at 11% to ammonium dihydrogen phosphate at 92%.

A. R. Macormac

Text. Research J. Oct. 1946

Spectrochemical Analysis

Analysis by excited atoms. Daniel Smith. *Interchem. Rev.* **4**, 67–74 (Autumn 1945).

A brief introduction to the principles of qualitative and quantitative spectrography with summaries of the external and internal standard procedures for spectrochemical analysis. E. N. Harvey, Jr.

Text. Research J. Oct. 1946

Spectroscopic Analysis of Gases

Analyses of mixtures of light gases by infrared absorption. Norman D. Coggeshall and Eleanor L. Saier. *J. Applied Phys.* **17**, 450–6 (June 1946).

Beer's law for the absorption of light is not applicable to the absorption of infrared by light gases such as CO, CO_2, SO_2, CH_4, N_2O, and HCl. Infrared absorption methods have been devised for the analysis of mixtures of such gases. The methods depend upon the pressure broadening of absorption bands as influenced by the various components of the mixture. The nature of the effects encountered and the accuracy of results obtainable with this type of analysis are discussed. Apparatus for standardized gas analysis by infrared spectroscopy is described. T. J. Dietz

Text. Research J. Oct. 1946

Determination of Uronic Acids

Determination of uronic acids. R. M. McCready, H. A. Swenson, and W. D. Maclay. *Ind. Eng. Chem., Anal. Ed.* **18**, 290–1 (May 1946).

An apparatus for the determination of uronic acids is described. The sample is digested with 19% HCl for 1.5 to 2 hrs. on an oil bath at 143°C. The CO_2 evolved is absorbed by alkali and the excess alkali titrated with standard acid. Results on citrus pectin, apple pectin, pectic acid, alginic acid, and galacturonic acid with the method proposed compare well with a 5-hr. digestion with 12.5% HCl. Inulin, gelatin, starch, sucrose, and mucic acid as impurities in moderate amounts did not interfere.

A. R. Macormac

Text. Research J. Oct. 1946

The Vectograph

Army inspection technique to aid textile industry. Harry F. Schoenfelder. *Am. Wool and Cotton Reptr.* **60**, 51, 53, 55, 57 (June 27, 1946).

An address describing the use of "vectographs" (3-dimensional pictures) as visual inspection gages to illustrate material defects, establish tolerance limits, and to obtain greater uniformity in the inspection of textiles and related items. Considerable work along this line has already been done by the Quartermaster Corps and 6,000 samples of fabric swatches have been catalogued to date. From these will be selected the swatches from which visual inspection gages will be

made. After the samples selected are approved by a standards committee, each swatch will be photographed and vectograph prints made. H. J. Burnham
Text. Research J. Oct. 1946

Water-Repellency

The water-repellency of fabrics and a new water-repellency test. S. Baxter and A. B. D. Cassie. *J. Text. Inst.* **36**, T67–90 (Apr. 1945).

The behavior of water drops on plane solid and ideal porous surfaces is analyzed in terms of surface energies and contact angles. Textile yarns and fabrics are unlike ideal porous surfaces in that, on continued exposure to rainfall, water films form between the fibers in the surface of the yarn and pearling subsequently ceases. Succeeding drops force the water farther into the pore and this process of penetration continues until the kinetic energy of the falling drop is insufficient to force the water column deeper into the pore. If the thickness of the fabric is greater than the maximum depth of penetration of the drops, no water will pass through, but if the thickness is less, penetration of water will occur. Thus the maximum absorption of a fabric and the penetration are determined by the fiber-water advancing contact angle and the physical construction of the fabric, while the rate of absorption depends on the effective receding contact angle and its decay with time. A "wetting test" was developed to study the formation of water films between fibers by observing the receding contact angle and its decay with time. The apparatus provides for immersing the yarn vertically in water and slowly withdrawing it. An image of the yarn at the surface of the water is projected on a screen. The time for the receding contact angle to decrease to 90° is taken as the wetting time. The wetting time is very sensitive to temperature, particularly the lower temperatures, as shown by tests on worsted yarns at temperatures ranging from 0 to 60°C. The importance of temperature control in water-repellency tests is thus indicated. An equation is developed for calculating the pressure required to force water between the fibers of a yarn. The pressure necessary to force water through a cloth, as measured by the hydrostatic pressure test, is much lower than the calculated pressure required to force water into the yarns of the fabric, showing that water forced through the fabric does not pass through the yarns themselves but through the pores between the yarns. 54 fabrics, both proofed and unproofed, ranging from wool greatcoat material to cotton drills and gabardines, were compared for water-resistant properties, using the hydrostatic pressure test, the Bundesmann test, and the wetting test. The properties measured by the different tests are analyzed and the results are compared with the mechanism by which rain is absorbed by a fabric. Conflicting results are ascribed to the fact that the different tests do not necessarily measure the same properties of the fabric. The general conclusions are that different proofing agents compared on cotton fabrics of one structure are placed roughly in the same order by all 3 tests. The wetting test is most sensitive for proofing efficiency of heavy wool cloths, followed by the Bundesmann test, while the hydrostatic pressure test is insensitive to proofing for these fabrics. The hydrostatic pressure test is considered of little value in indicating the relative merits of different structures for rain-resistance, while the Bundesmann and wetting tests both agree with theory in indicating that a low porosity need not mean a structure of good rain-resistance. In evaluating weathered waterproof cloths, the hydrostatic pressure test failed to indicate changes over weathering periods of as long as 6 mos., even though the rain-resistance of the fabrics had visibly deteriorated. Ideal structures for rain-resistance are discussed, and duck feathers and animals' fur are cited as nearly ideal examples occurring in nature. The requirements for a water-repellent fabric are that the fibers shall be spaced uniformly and as far apart as possible and that they shall be held so as to prevent their ends drawing together. The conception of gabardine as a rain-resistant fabric is contrary to this deduction, while Scottish tweed, highly regarded by the countryman for its rain-resistance, conforms more closely to these requirements than almost any other fabric. R. K. Worner
Text. Research J. Oct. 1946

Yarn Appearance Standards

Yarn appearance photographic standards. J. DeLaRama, Jr. *Textile Bulletin* **70**, 22, 23, 44, 45 (July 1, 1946).

A report on a study of various methods of photographing yarn appearance boards. An easel method and a glass-plate method are described. Identical results are said to be achieved from both methods but the glass-plate method is said to entail less manipulation, thereby eliminating the hazard of maladjusting the yarn traverse on the board. H. J. Burnham
Text. Research J. Oct. 1946

CHEMICAL AND PHYSICAL RESEARCH

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Absorption of Liquids by Cellulose

Density of cellulose fibers. I. Introduction and experiments on the penetration of liquids into dry cellulose. P. H. Hermans and D. Vermaas. *J. Polymer Sci.* **1**, 149–55 (May 1946).

The pores in cellulose are coarse enough to be easily filled with liquid and therefore should not interfere with density determinations. It is shown with model viscose fibers that indifferent organic liquids like toluene do not penetrate into dry cellulose and that even water and glycerol penetrate very slowly. In the experiments with water vapor, a new phenomenon, the heterogeneous course of absorption, is observed as sharp microscopically visible boundary

lines between the wet and dry portion of the fiber. E. D. Klug
Text. Research J. Oct. 1946

Density and Refractivity of Cellulose

Density of cellulose fibers. II. Density and refractivity of model filaments. P. H. Hermans, J. J. Hermans, and D. Vermaas. *J. Polymer Sci.* **1**, 156–61 (May 1946).

Accurate determinations of density and refractive power on 3 types of model viscose filaments, (1) isotropic, (2) steamed isotropic which have less swelling power and sorptive capacity, and (3) high oriented, were made. The refractive index was determined by the immersion method with butyl stearate-tricresyl phosphate, special techniques being used to exclude moisture. The molecular refractivity was in excellent agreement with that calculated with the Gladstone-Dale equation. The densities were determined by the floating method in carbon tetrachloride-nitrobenzene, which does not penetrate the fiber substance.
Text. Research J. Oct. 1946 E. D. Klug

Density of Cellulose

Density of cellulose fibers. III. Density and refractivity of natural fibers and rayon. P. H. Hermans, J. J. Hermans, and D. Vermaas. *J. Polymer Sci.* **1**, 162–71 (May 1946).

The density of various fibers including ramie, several types of viscose, bleached and standard cotton, wood pulp and Bemberg rayon were determined by the floating method in carbon tetrachloride. Moisture was excluded by drying at 100°C, removing air with dry CCl_4 at 100°C, and finally condensing CCl_4 on the sample. The density was derived from the temperature at which the sample neither sinks nor floats. This method gives values which are about 0.7% high, proved to be due to a slight absorption of CCl_4 by the fibers at elevated temperatures. The densities of native ramie and cotton are considerably higher than those of regenerated cellulose with wood pulp intermediate. The densities of different regenerated celluloses show very slight variations, 1.518 to 1.525. The density of ramie mercerized without tension is slightly higher than the highest value for rayon. E. D. Klug
Text. Research J. Oct. 1946

Oxidation of Cellulose

Chemical changes which take place in the cellulose macromolecule in copper-ammonia solution under the influence of atmospheric oxygen. V. I. Ivanov and E. D. Stakheeva-Kaverzneva. *Compt. rend. acad. sci. U.R.S.S.* **48**, 405–8 (1945) (in English)(through *Chem. Abstr.* **40**, 3894[8] (July 10, 1946)).

Passage of air through a 2–3% solution of cellulose (*I*) in cuprammonium hydroxide at 15° for 20–30 days transforms 8% of the *I* into low-molecule decomposition products; at 30°, 25% of the *I* is decomposed. The decomposition products of *I* and those obtained on hydrolysis of the oxidized *I* by 0.2*N* HCl were (in mols. per number of glucose radicals in the *I*): formic acid 1:2180, 1:192; acetic acid 1:127, 1:96; oxalic acid, traces in each; glycolic acid, none, traces; erythronic acid, none in each; arabonic acid,—and present; gluconic acid,—and present; glucuronic acid (*II*), 1:61 in each; formaldehyde, absent, present; acetaldehyde, absent in each; furfural, present in each; CO_2 absent in first products. From the yield of *II*, it follows that 1 glucose radical of every 30 in the *I* is oxidized, 50% of these oxidized radicals passing into solution. Such mild oxidation decreases the viscosity of the *I* solution nearly to that of the original solvent. The lower aliphatic acids were produced by secondary reactions. The product and their ratios class the oxidation process as a reaction which begins with the oxidation of the 6th C atom in the glucose radical. The data do not support the oxidation scheme of Staudinger (*C.A.* **33**, 9291[5]). The mechanism of the decomposition of the *I* macromolecule in alkaline solution under the action of oxidizing agents is discussed.
Text. Research J. Oct. 1946

Transformations of the macromolecule of celullose in an ammoniacal solution of cupric hydroxide. O. P. Golova. *Compt. rend. acad. sci. U.R.S.S.* **47**, 31–2; *Doklady Akad. Nauk S.S.S.R.* **47**, 32–3 (1945) (in English); cf. *C.A.* **40**, 1653[9] (through *Chem. Abstr.* **40**, 3895[2] (July 10, 1946)).

After the elimination of air from the cuprammonium solution and from the histological canals of cellulose (*I*) fibers, the degree of polymerization (D.P.) was 9,500–10,000 glucose units in the chain, corresponding to a mol. wt. of 1,620,000. This is not the maximum value for native *I*, because of the purification to which the *I* has been subjected. This is true also because of the change in viscosity of *I* in the presence of 0. The introduction of 3.57×10^{14} mols. of 0 into a cuprammonium solution of *I* changes the viscosity so that the D.P. is 2,500–3,000 glucose units; 0.6×10^{20} mols. of 0 decreases the D.P. to 50–60 glucose units. The oxidized cellulose isolated from such solutions, examined by the iodine-number method of Bergman and Machemer (*C.A.* **25**, 1071) and by the determination of the yield of glucuronic acid (*cf.* preceding abstract), also gives values of 50–60 glucose units.
Text. Research J. Oct. 1946

Cellulosic Rayons

The structure of cellulosic rayons. Part III. Chain-length determinations in cuprammonium solution. Frank Howlett, Elizabeth Martin, and Joan Swan. *J. Text. Inst.* **37**, T77–88 (Apr. 1946).

Following Part II in which a series of K_m constants in the Staudinger equation, $\lim_{c \to 0} \eta_{sp}/c = K_m \cdot l$, were determined for cellulose acetates in organic solvents, in this paper the authors extend the above series of K_m constants to include values for celluloses dissolved in cuprammonium. The authors find that the viscosities of solutions of viscose rayon vary with the concentration

according to the Baker equation, $\eta_r = (1 + p \cdot c)^n$, where η_r is the relative viscosity, p is a constant, and n has any integral value between 6 and 10. Two methods of evaluating K_m, the constant relating intrinsic viscosity to chain length, for celluloses in cuprammonium were investigated, both depending on the use of celluloses derived from esters, the chain lengths of which were determined by the methods described in Part II of this series. The value of K_m obtained from Kraemer's ultracentrifuge results for secondary cellulose acetate in acetone solution—4.3×10^{-4}—was accepted as a provisional standard, and from this the value of K_m for cellulose in cuprammonium was found to be 2.5×10^{-4}; this value was used to determine the chain lengths of various rayons. The corresponding value of K_m calculable from Kraemer's data provided for solutions of cellulose in cuprammonium is 3.8×10^{-4}, 50% greater than the value obtained by the authors. The cause of this discrepancy is not known. Determinations of K_m for secondary cellulose acetates dissolved directly in cuprammonium gave the value 2.8×10^{-4}, showing the influence of the acetic acid liberated in the hydrolysis of the acetate. The relation previously found between the slope and the zero intercept of the plot of log (η_{sp}/c) against c was found to hold for solutions of rayons in cuprammonium. E. Pacsu

Text. Research J. Oct. 1946

The structure of cellulosic rayons. Part IV. The solubility and fractionation of secondary cellulose acetate. F. Howlett and A. R. Urquhart. *J. Text. Inst.* **37**, T89–112 (Apr. 1946).

The paper describes an investigation of the solubility in a series of mixtures of a solvent with a nonsolvent of a secondary cellulose acetate rayon produced by Courtaulds, Ltd., and sold under the name "Seraceta." The material was in the form of a continuous filament yarn (140 den. 28 fil.), was freed from oil before use, and had an acetic-acid yield of 53.6%. The objects of the investigation were to evolve a suitable technique, and to ascertain to what extent information about the chain length heterogeneity of the material could be derived directly from the solubility curve. The effect of temperature on solubility has been studied, and a limited series of solubility determinations have been made on acetates of varied physical forms and different acetic-acid yields; the effect of oxidation with 0.1 *N* sodium hypochlorite at pH 7 of the acetate has also been examined. The information provided by the solubility curves led to the development of a fractionation method using acetone as solvent and *n*-butyl acetate as diluent, and this was used to fractionate a secondary cellulose acetate and an oxidized product obtained from it. Various characteristics of the fractions have been measured, and weight- and number-distribution constructed for the two materials. The authors emphasize that while no claim is made that the acetone-butyl acetate method adapted for the fractionations is necessarily the best method of fractional solution that could be devised, yet the method does achieve the fractionation of cellulose acetate reproducibly and without degradation.

Text. Research J. Oct. 1946 E. Pacsu

Structure of Copolymers

Intramolecular reactions in vinyl polymers as a means of investigation of the propagation step. E. Merz, T. Alfrey, and G. Goldfinger. *J. Polymer Sci.* **1**, 75–82 (Mar. 1946).

The Flory-Wall expressions for the fraction of substituents remaining on a vinyl copolymer, when substituents are removed at random from adjacent 1,3 positions, are extended to the case of nonrandom copolymerization. A copolymer composition equation is derived for the case in which the type of monomers preceding the active free radical chain end affects the propagation reaction. The distribution of lengths of sequences in copolymers is discussed. Authors

Text. Research J. Oct. 1946

Effect of Heat on Fibers

Effect of heat on wool, cotton, and nylon. A. O. Lloyd. *Nature* **157**, 735–6 (June 1946).

A study of the pH and electrical conductivity of water extracts of wool, cotton, and nylon heated at 150°F for varying periods of time is described. Data are given which show that the pH decreases and the conductivity increases as the heating period increases. After 12 hrs., the pH and conductivity of the nylon extract remained constant, but the data for wool and cotton show continued change.

Text. Research J. Oct. 1946 R. W. Eyler

Experiments with Fiber Models

Model experiments on fiber molecules. H. A. Stuart. *Z. Elektrochem.* **50**, 67–70 (1944) (through *Chem. Abstr.* **40**, 3963[2] (July 20, 1946)).

The behavior (flexibility, degree of order, etc.) of long-chain mols. in the pure liquid and in solution is illustrated by means of a model made of glass beads.

Text. Research J. Oct. 1946

Structure of Pectin

The optics and fine structure of pectin and its derivatives. K. Wuhrmann and W. Pilnik. *Experientia* **1**, 330–2 (1945) (in German) (through *Chem. Abstr.* **40**, 3963[3] (July 20, 1946)).

Fibers and films of pectin showed a negative double refraction. According to x-ray diagrams the demethoxylated specimens "crystallized" in a higher degree than the original pectin. Calculation seems to support the hypothesis of folded chains.

Text. Research J. Oct. 1946

Properties of Plastic Solutions

Characterization of cellulose derivatives by solution properties: Plasticizers as solvents. H. M. Spurlin, A. F. Martin, and H. G. Tennent. *J. Polymer Sci.* **1**, 63–74 (Mar. 1946).

The dimensional stability of thermoplastics is a function of the extent to which stresses due to nonviscous flow at molding temperatures are frozen into the plastic. With solvent-type plasticizers, fewer stresses will be frozen in with plasticizers of best solvent power. The slope of the reduced viscosity-concentration curve is suggested as a measure of solvent power. Intrinsic viscosity in a given plasticizer is not a good measure of its solvent power. A theory of the action of nonsolvent plasticizers is given with an electron micrograph showing the structure. Methods of predicting the behavior of nonsolvent plasticizers from behavior in solution, osmotic pressure, and vapor pressure measurements are suggested. E. D. Klug

Text. Research J. Oct. 1946

Thermodynamics of Polymers

Statistical behavior of the single chain molecule and its relation to the statistical behavior of assemblies consisting of many chain molecules. Werner Kuhn and Franz Grün. *J. Polymer Sci.* **1**, 183–99 (May 1946).

A thermodynamic analysis.

Text. Research J. Oct. 1946 E. D. Klug

BLEACHING: DYEING: FINISHING

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Peroxide Bleaching

Some aspects of peroxide bleaching. I. W. J. MacNab. *Fibres, Fabrics & Cordage* **12**, 487, 489, 491, 509 (1945); **II.** *Ibid.* **13**, 16–19 (1946) (through *Chem. Abstr.* **40**, 4891[8] (Aug. 20, 1946)).

A discussion of the manufacture of H_2O_2, bleaching with H_2O_2, versatility of peroxide bleaching, a bleaching installation, a detailed recipe for bleaching cotton and linen yarn, piece bleaching of linen and cotton with peroxide, control of the peroxide bath, experiments in bleaching linen piece goods, the continuous peroxide bleaching process, American practice, and jute bleaching. Conclusion: The ever-increasing use of H_2O_2 in bleaching has justified the claim that it is safe and cheap to use and gives results unequalled by any other method.

Text. Research J. Oct. 1946

Continuous Bleaching

Wartime advances made in continuous bleaching. DeHaven Butterworth. *Am. Wool and Cotton Reptr.* **60**, 13, 46 (June 6, 1946); cf. *Rayon Text. Mo.* **27**, 320 (June 1946).

Big savings are reported to result in the use of continuous bleaching over kier-boiling in floor space, cost of labor and chemicals, steam consumption, equipment, and time. A comparative chart on daily production of 36 tons of 5-yd. goods is shown. Quality is said to be equal.

Text. Research J. Oct. 1946 H. J. Burnham

Osage Orange Pigments

Osage orange pigments. XI. Complete structures of osajin and pomiferin. M. L. Wolfrom, W. D. Harris, G. F. Johnson, J. E. Mahan, S. M. Moffett, and B. Wildi. *J. Am. Chem. Soc.* **68**, 406–18 (Mar. 1946).

The yellow pigments of the fruit of the osage orange (*Maclura pomifera* Raf.) are osajin and pomiferin. Both are yellow mordant dyes for animal fibers but the chief absorption band for each has a maximum around 2800 Å. Both compounds isomerize in the presence of mineral acids to yield high-melting, colorless products, iso-osajin and isopomiferin. Structures of each are given. Pomiferin and isopomiferin differ only in the presence of another OH group on the 3′ position. Extensive data are presented to prove the correctness of the structure given.

A. R. Macormac

Text. Research J. Oct. 1946

Cleansing Agents for Textiles

Enzymic cleansing agents for textiles. Juan B. Puig. *Ion* **6**, 85–9, 137–41 (1946); cf. *C.A.* **39**, 1763[4] (through *Chem. Abstr.* **40**, 4527[8] (Aug. 10, 1946)).

A review and discussion of enzymes which can substitute for soap in the textile industry. Pancreatin contains trypsin which transforms albuminoids into peptones, steapsin which emulsifies fats, and amylopsin which hydrolyzes carbohydrates.

Text. Research J. Oct. 1946

Persulfates

The use of persulfates in the textile-finishing industry. Eugen Klenk. *Melliand Textilber.* **25**, 351–5 (1944) (through *Chem. Abstr.* **40**, 4891[5] (Aug. 20, 1946)).

Detailed information is given on the chemical constitution and properties of alkali peroxydisulfates ($M_2S_2O_8$) with emphasis on those properties of importance to the textile-finishing industry such as their behavior toward metals, metallic ions, and catalysts. Analytical data are given and the applications of peroxydisulfates as bleaching agents are described. By means of new investigations it was determined that the bleaching action of peroxydisulfates on natural and synthetic cellulose fibers, particularly at elevated temperatures, is unsatisfactory. Furthermore, at the higher temperatures there are very serious attacks on the fiber. For special purposes it is possible to bleach cellulose fibers at temperatures below 50°. Peroxydisulfates exhibit no distinct bleaching action on ordinarily dyed wool. However, they are very suitable for the bleaching of wool and animal hairs of natural color, especially in combination with H_2O_2. The chief application of peroxydisulfates is the after-oxidation of S and vat dyeings. Peroxydisulfates can be used also for the manufacture of starch sizes and desizing.

Text. Research J. Oct. 1946

Resin Finishing

The mechanics of zone control in resin finishing. Northern New England Section A.A.T.C.C. *Am. Dyestuff Reptr.* **35**, P13–19 (Jan. 14, 1946).

Wool, cotton, and rayon materials were treated with methylol melamine formaldehyde resin in two ways: (1) in a 10% solution in water, resulting in good penetration into the material, and (2) in a 10%

solution in alcohol-water (2–1), which resulted in deposition of the resin principally upon the surface of the material. The differences in physical properties resulting from the difference in zone of application of the resin were studied. Some of the properties included were strength, elongation, stiffness, resilience, thermal transmission, and shrinkage. K. S. Campbell

Text. Research J. Oct. 1946

FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

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Cottonized Bast Fiber

Cottonized bast fiber. II. Comparison of staple diagrams and properties of three-cylinder mixed yarn containing bast fiber cottonized by different methods. J. B. A. Stroink, H. J. Bendel, and D. A. Beerens. *Melliand Textilber.* **25**, 217–21 (1944); cf. *C.A.* **39**, 4228[5] (through *Chem. Abstr.* **40**, 4888[8] (Aug. 20, 1946)).

The shortening of the staple during alkaline cottonization of flax is due not merely to the degradation of the intercellular layers but also partly to a chemical action on the cellulose complex, with formation of oxycellulose. Alkaline treatment in the presence of hyposulfite has little effect on the yield of fibers of desired staple, but affects chiefly the quantity of fibers either longer or shorter than the optimum (16–36 mm.). Pretreatment with pancreatic enzyme increases the yield of desired staple; this is explained by the fact that diastase which was not washed out improves the protective effect against oxidizing agents. These results led to a method of treatment which includes pretreatment with pancreatic enzyme in a neutral medium, activation of the proteases by the use of NH_3, and a faintly acid bleach. Various staple diagrams obtained under different conditions are discussed. The treatment with alkalies after acid chlorination is considered to be necessary because the solution of chlorinated proteins and lignins prevents the fibers from becoming glued together again. **III. Relation among copper number, degree of polymerization, and staple diagram.** *Ibid.* 253–5. The Cu number of retted flax after treatment with enzyme drops from 3.07 to 1.46; thus, half of the reducing components are degraded by the enzyme. The Cu number of retted flax, which had decreased after enzyme treatment, increased again on acid chlorination, as not all easily hydrolyzable constituents are removed by the enzyme. Without enzyme treatment, the Cu number of the retted flax rises more than that of the treated material. No chemical cottonization of flax can be limited exclusively to the intercellular incrustations, or conducted in such a way that the morphological "elementary fibers" can be set free. There is always a certain influence on the primary wall or the cellulose complex. Alkaline boiling, particularly under pressure, leads to oxidation in the alkaline medium. The chain length is affected before the intercellular layer is completely dissolved or before the cross-linkages between the fiber bundles are disrupted. While the larger bundles are still present pieces of the elementary fibers are broken off, leaving an undesirable mixture of too-long and too-short fibers. Furthermore, alkaline boiling produces products (consisting perhaps of hemicellulose) which on drying cause the fibers to adhere together. The partial removal of incrustations and proteins by pancreatic enzymes and later acid chlorination refine the staple without shortening it too much. Alkaline boiling following the acid chlorination removes the last lignin residues, removes roughness, and sets the hemicelluloses free. **IV. The chemical cottonization of green flax.** *Ibid.* 289–90. Retting flax by the method of Dutch Patent 44,836 (*C.A.* **33**, 4438[9]) followed by treatment with 0.5% HCl and, finally, washing gave a good yield of longer and better-quality fiber than did biological retting. The Cu number of the flax is lowered somewhat more by boiling with a neutral salt than by enzymes; this indicates a thorough degradation of the pectin. After acid chlorination the Cu number of flax increases; this shows that acid chlorination hydrolyzes the impurities (that were not removed by pretreatment) to strongly reducing compounds. The degrees of polymerization make it evident that flax cellulose differs fundamentally from cotton cellulose, and that the former is somewhat affected by the neutral-salt treatment. The staple diagram of green flax retted with neutral salt is similar to that of biologically retted flax after-treated with enzyme. The treatment with acid hypochlorite improves the staple diagram. A 6% oxalate solution causes improvement in the absence of chlorination; subsequent chlorination with 5 g./l. Cl produces a favorable diagram but one which is not as good as that produced by chlorination after enzyme treatment of retted flax. The diagram can be improved also by extension of the boiling period. The fiber treated with neutral salts is less pliant than fiber produced by biological retting and enzymic cottonization.

Text. Research J. Oct. 1946

Redwood Fiber

Palconia—a new vegetable fiber. C. J. Jones. *Fibres, Fabrics & Cordage* **13**, 113 (1946) (through *Chem. Abstr.* **40**, 4888[4] (Aug. 20, 1946)).

This fiber is made from the bark of the redwood tree; it is not as flexible and pliable as wool. Mixtures with wool are suitable for the manufacture of hats. The dyeing process and dyes used conform to those applicable for the dyeing of cotton. Applications in the manufacture of fulled cloth are indicated.

Text. Research J. Oct. 1946

Effect of Stretch on Yarns

Practical effect of stretching synthetic yarns. Piedmont Section A.A.T.C.C. *Am. Dyestuff Reptr.* **35**, P26–8 (Jan. 14, 1946).

A study has been made of stretching, such as would occur in warp sizing, on the subsequent properties of synthetic yarns. A general conclusion reached is that, if a yarn is

permitted to retain at least 15% (the actual amount varying with each class of fibers) of its original total elongation, it can withstand all of the mechanical effects incident to processing. K. S. Campbell
Text. Research J. Oct. 1946

Deterioration of Jute by Superphosphate

The deterioration of jute materials in contact with superphosphate and mixtures containing superphosphate. L. J. H. Teakle and H. E. Hill. *J. Roy. Soc. W. Australia* **30**, 1–13 (1943–44) (pub. 1946) (through *Chem. Abstr.* **40**, 4892[6] (Aug. 20, 1946)).

Examination of jute sacks used in storing superphosphate and laboratory tests using strips from jute sacks conclusively showed that damage from superphosphate occurred under a range of conditions. Damage consisted of a brownish-red discoloration, loss of tensile strength, and extreme brittleness when injury was severe. The damage is caused by substances of an acidic nature of which HCl, HF, and excess H_2SO_4 and H_3PO_4 are most important. Of these, HCl and HF are most destructive and especially is this true at elevated temperatures. H_2SO_4 and H_3PO_4 become damaging chiefly when contact is prolonged over long periods of time. Control measures were described and include spraying alkaline solutions on the topmost bags in piles and the incorporation of $CaCO_3$ into the superphosphate before bagging.
Text. Research J. Oct. 1946

Theory of Felting

The manufacture of thin felt from mordant-treated rabbit or hare hairs. A theory of felting. Gottfried Berg. *Melliand Textilber.* **25**, 221–4 (1944); cf. *T.R.J.* **16**, 45 (1946) (through *Chem. Abstr.* **40**, 4892[3] (Aug. 20, 1946)).

The physical conditions of fiber combination were studied throughout the whole felting and fulling process. The effect of carroting on the physical structure is discussed in detail. Rabbit and hare hairs can be caused to curl spontaneously if they are treated with solutions of high oxidizing powers and a correspondingly high H-ion concentration and if these solutions are allowed to dry.
Text. Research J. Oct. 1946

MISCELLANEOUS

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Air Conditioning

Principles of air conditioning. John Duerst. *Cotton* **110**, 78, 79 (June 1946).

An elementary discussion of the principles of air conditioning with examples of the use of scientific data applied to same.
H. J. Burnham
Text. Research J. Oct. 1946

Asthma Among Fur Workers

Studies with *p*-phenylenediamine in fur workers. Mabel G. Silverberg and Harry Heimann. *N. Y. State Dept. Labor, Monthly Review, Div. Ind. Hyg. & Safety Standards* **25**, No. 6, 4 pp. (1946) (through *Chem. Abstr.* **40**, 4892[4] (Aug. 20, 1946)).

The work is directed toward finding a reliable test to relate the occurrence of asthma in fur workers to exposure to *p*-phenylenediamine. A clinical study of 10 workers with asthma and 4 groups totaling 85 persons without asthma as control cases was made involving scratch tests with various furs and danders, and solutions of *p*-phenylenediamine, and patch tests with 2% *p*-phenylenediamine in petrolatum. Scratch tests with *p*-phenylenediamine in the asthmatics were negative. In one of the 10 asthmatics scratch tests with animal epidermals were positive. 4 of the 10 asthmatics in the fur industry (3 of whom had no dermatitis or history of dermatitis) gave a positive reaction to patch test with *p*-phenylenediamine. Patch tests with *p*-phenylenediamine on fur workers who had neither asthma nor occupational dermatitis were negative.
Text. Research J. Oct. 1946

Cotton Industry Survey

What I saw of the cotton industry in England, U.S.A., and Switzerland. M. Viswanathan. *Indian Text. J.* **66**, 294–7 (Jan. 1946).

Impressions are given of equipment, production methods, and management of cotton mills in the 3 countries. R. K. Worner
Text. Research J. Oct. 1946

Dye Nomenclature

Dyestuff nomenclature. C. L. Bird. *J. Soc. Dyers and Colourists* **61**, 321–8 (Dec. 1945).

An extensive list of brand names of all classes of British, French, and Swiss dyes together with their uses, chemical constitution, and maker's name. A further list summarizes information on brand letters as normally appended to brand names.
Text. Research J. Oct. 1946 K. S. Campbell

Natural Dyes

Colors for textiles: Ancient and modern. Max Bender. *Interchem. Rev.* **4**, 75–87 (Autumn 1945).

Descriptive and historical discussion of dyes, chiefly natural colors such as indigo, woad, logwood, madder, Tyrian purple, kermes, cochineal, etc. Colors used by the American Indians, mordants and other auxiliary compounds, modern dyes and pigments for textile printing are also briefly covered. 19 references. E. N. Harvey, Jr.
Text. Research J. Oct. 1946

Atomic Physics

A brief review of atomic physics. David B. Pall. *Interchem. Rev.* **5**, 12–18 (Spring 1946).

The fundamentals of nuclear physics and atomic power are presented from the elementary viewpoint.
E. N. Harvey, Jr.
Text. Research J. Oct. 1946

Stability of Cellulosic Plastics

Dimensional stability of cellulose thermoplastics. W. E. Gloor. *Product Eng.* **16**, 554–7 (1945)

(through *Chem. Abstr.* **40**, 4249[5] (July 20, 1946)).

A discussion of the effect of extreme climatic conditions. Experimental data are tabulated.

Text. Research J. Oct. 1946

Static

Static eliminated by grounding or neutralizing. H. S. Knowlton. *Textile World* **96**, 110–3, 115 (June 1946).

A discussion on the formation of static on textile fibers during processing and means of combating it, particularly by the use of eliminators and neutralizers.

H. J. Burnham

Text. Research J. Oct. 1946

Disposal of Textile Effluents

Effluent treatment and solids recovery. II. Textile and rayon industries. H. Robinson. *Ind. Fibres, Synthetics & By-Products* **7**, 378–82 (1945) (through *Chem. Abstr.* **40**, 4828[1] (Aug. 20, 1946)).

A detailed description is given of the characteristics of the various types of effluents from textile processes and of the layout of a disposal system for a plant manufacturing acetate rayon. A flow sheet for the treatment of textile-works effluent, a suitable continuous-flow settling tank in operation, and a section of a model of the latter tank giving details of construction are shown.

Text. Research J. Oct. 1946

Textile Knots

Let's knot and let's do it the right way. Anon. *Textile World* **96**, 101–5 (June 1946).

Instructions with step-by-step pictures for tying the weaver's knot, the double weaver's knot, the velvet weaver's knot, the short-end transfer knot, and the creeler's knot.

H. J. Burnham

Text. Research J. Oct. 1946

Terminology of Viscosity Functions

The terminology of intrinsic viscosity and related functions. L. H. Cragg. *J. Colloid Sci.* **1**, 261–9 (May 1946).

The confusion existing in the use of symbols and names for Kraemer's "intrinsic viscosity" is illustrated with numerous examples from the literature. The following terminology is suggested: η_{sp}, "specific viscosity"; η_{sp}/c, "reduced viscosity"; $(\ln \eta_r)/c$, "inherent viscosity"; $[\eta]$, "intrinsic viscosity"; whether determined as "limiting reduced viscosity," $\lim_{c\to 0} (\eta_{sp}/c)$, or "limiting inherent viscosity," $\lim_{c\to 0} [(\ln \eta_r)/c]$, or as "limiting viscosity concentration coefficient," $\lim_{c\to 0} (d\eta_r/dc)$. The importance is stressed of indicating whether values are true viscosities η, kinematic viscosities ν, or flow times t without kinetic energy correction. Where the values correspond to ν or t, these should be used in the above mathematical expressions, e.g., $[\nu]$ or $[t]$ instead of $[\eta]$. E. D. Klug

Text. Research J. Oct. 1946

German Textile Technology

German textile technology can advance U. S. industry. *Textile World* **96**, 101–15 (May 1946).

Résumés of the significant aspects of 11 reports of textile investigators sent to Germany following VE Day as part of the Technical Industrial Intelligence Corps. Reports are covered of the teams on finishing, worsted-type synthetics, synthetic dyeing, sizing of synthetics, PeCe fiber, ring spinning of wool, cotton-spinning innovations, textile printing, wool dyeing, circular knitting, and screen printing. 80 reports which have been made available and the 60 investigators are listed.

H. J. Burnham

Text. Research J. Oct. 1946

Japanese Textile Survey

Japanese textile industry surprised investigators. Frank E. Rowe. *Am. Wool and Cotton Reptr.* **60**, 11, 12 (July 11, 1946).

An address outlining findings of the speaker as a member of the group sent by the government to investigate the present textile situation in Japan. H. J. Burnham

Text. Research J. Oct. 1946

John Mercer

Mercer and mercerization. A. W. Baldwin. *Indian Text. J.* **56**, 253–6 (Dec. 1945); *Endeavor* **3**, 138–43, 149 (1944).

A review. R. K. Worne

Text. Research J. Oct. 1946

Constituents of Wool Fat

Constituents of wool fat. I. Review of the subject to date. Léon Velluz and Edgar Lederer. *Bull. soc. chim. biol.* **27**, 211–18 (1945). **II. Chromatographic study of the unsaponifiable fraction.** David Daniel, Edgar Lederer, and Léon Velluz. *Ibid.* 218–25 (through *Chem. Abstr.* **40**, 4897[8] (Aug. 20, 1946)).

The unsaponifiable fraction was dissolved in petroleum ether and passed through a column of Al_2O_3. The first filtrate contained a very small amount of a mixture of paraffin hydrocarbons. Successive fractions obtained by adsorption and elution contained: (1) a very small amount of unidentified unsaturated *d*-rotatory steroid ketones; (2) cholesta-3,5-dien-7-one, strongly *l*-rotatory, about 0.6% of the original lanolin; (3) "isocholesterol" (a mixture of lanosterol, dihydrolanosterol, γ-lanosterol, and agnosterol), 20–26% of the lanolin; (4) cholesterol, 20–30% of the lanolin; and (5) a mixture of dextrorotatory substances amounting to 5% of the lanolin. Lanolin also yielded 2–6% of β-cholestanol (method of separation not given). The cholesta-3,5-dien-7-one does not exist as such in lanolin; it is formed from esters of 7-ketocholesterol during the saponification. **III. Determination of "isocholesterol."** Edgar Lederer and Tchen Pau Kiun. *Ibid.* 419–24. "Isocholesterol" (*cf.* above) is determined by a slight modification of the Burchard-Liebermann reaction. "Isocholesterol" is present in the hair-fat of the sheep, goat, llama, and dromedary but not in the hair-fat of the ox, rabbit, or hare, nor in human hair.

Text. Research J. Oct. 1946

WAR RESEARCH ON TEXTILES*

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British Test Methods

Report on visit to industrial centers in the north of England, at Leeds, Manchester, Nottingham, Langley Mills. (FIAT Final Report 284.) Herbert Schiefer. PB 22418, Aug. 1945; 7 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 221 (July 19, 1946)).

The purpose of this visit was to discuss with experts research in textiles, testing equipment, test methods, standards and specifications. The report records what was being done at the following places: Leeds University; Wool Industry Association, Leeds; Shirley Institute, Manchester; College of Technology, Manchester; Aristoc Hosiery Mills, Nottingham. The scientists contacted had no information concerning developments in Germany.

Text. Research J. Oct. 1946

Research in Switzerland

Textile research personality, institutions, and researches on textile testing, instruments, methods, standards and on properties of textile fibers in Switzerland. (FIAT Final Report 306.) Herbert F. Schiefer and Richard T. Kropf. PB 22420, Oct. 1945; 6 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 151 (July 12, 1946)).

This report consists of brief presentations of the following Swiss research personalities: Prof. Dr. A. Frey-Wyssling, Prof. Dr. Ing. F. Honegger, Prof. Dr. L. Rüžička; the following Swiss organizations: Henry Baer and Company, manufacturers of technical apparatus and precision instruments for the textile industry, Eidgenössiche Material-prüfungs—und Versuchsanstalt für Industrie, Verein Schweiz. Maschinen Industrieller, and the Swiss Federal Institute of Technology; and the progress of the protein fiber "Eva." A bibliography is included.

Text. Research J. Oct. 1946

* Copies of the original reports abstracted in this section may be obtained from the U. S. Department of Commerce, Office of Technical Services, Washington 25, D.C.

U. S. Research

Durability Tests

Report of test of clothing, H. B. T., impregnated, residual strength: QMB T-1259. (Project T-214.) U. S. War Department. Quartermaster Board. PB 21843, Mar. 1944; 5 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 1432 (June 14, 1946)).

Tests were made of the wearing qualities of solution-impregnated herringbone twill jackets and trousers, the fabric of which had been reduced in strength 30, 45, and 60% of its original tensile strength by artificial deterioration. These garments were worn by 24 men when traversing the combat course at Edgewood Arsenal and a complete daily record was kept of all fabric and constructional failures and the number of times each garment traversed the combat course. It was concluded that 30% reduction of the tensile strength of this clothing removed approximately 85% of the usable life of the garment, and that there is no significant difference in the serviceability of clothing in which the tensile strength of the fabric is artificially reduced 30, 45, or 60% by storage under simulated tropical conditions. The removal of 30% of the tensile strength brings the test garments so close to the end-point of wear that further strength reductions are not significant.

Text. Research J. Oct. 1946

Report of test of trousers, cotton, field (9-oz. sateen). (Project T-199.) U. S. War Department. Quartermaster Board. PB 20560, June 1943; 5 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 1432 (June 14, 1946)).

Procedure and findings of test made to determine relative durability of various types of sateen are described. The report concludes that, on the basis of the test, the Nos. 4 and 5 harness sateen weave are approximately equal in resistance to snagging and resistance to abrasion; the back (twill in) of the Nos. 4 and 5 harness sateen weave is superior to the face (twill out) of the Nos. 4 and 5 harness sateen weave for resistance to abrasion.

Text. Research J. Oct. 1946

Tent Design

Tent design and construction. (QM Textile Series, Report 15; QM Tent Res. Report 1.) W. R. Barnes. PB 27728, May 1946: 110 pp.; microfilm, $3.00—photostat, $8.00 (through *Bib. Sci. and Ind. Reports* **2**, 307 (July 26, 1946)).

This study conducted at the Institute of Industrial Research at the University of Louisville under contract with the National Research Council was the result of reports of tent failures from the Pacific early in the war. It is a study of the structural principles involved, particularly of the stresses and strains which develop in a textile fabric when employed as a tent roof, as a basis for re-design of the M-1942 squad tent. It also includes other phases such as the problem of heating and ventilation in tents. It consists of the following sections: I. Structural stresses and strains in tents, by W. R. Barnes; II. Load-elongation-time curves of cloth, webbing, and rope, by G. W. Williams; Temperature control in tents, by R. L. Harvin. Comments by Rogers B. Finch. Drawings, photographs, and graphs illustrate the study.

Text. Research J. Oct. 1946

Shrinkage in Wool Socks

Preliminary report of study of shrinkage, causes of (socks with wool field formula). (Project S-79.) U. S. War Department. Quartermaster Board. PB 20551, Jan. 1944; 9 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib.*

Sci. and Ind. Reports 1, 1432 (June 14, 1946)).

Procedures and findings of tests are described. It is recommended that sudsing be considered the prime cause of shrinkage of wool socks when laundered by the present wool field formula; that socks, types 25 and 26, and enzyme-treated socks be considered superior to the untreated control socks with regard to resistance to shrinkage resulting from laundering.
Text. Research J. Oct. 1946

Storage of Clothing

Deterioration of protective clothing stored in standard packing boxes on the island of Oahu. (CWS 43rd Chemical Lab. Co. Tech. Rept. 56.) Ben W. Smith, Jr. PB 27658, Nov. 1944; 7 pp.; microfilm, $1.00—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* 2, 365 (Aug. 2, 1946)).

In an effort to determine the actual condition of impregnated coveralls after approximately 18 months' storage under normal conditions on the island of Oahu, samples from several batches impregnated in a processing plant on this island were tested for CC-2 content and tensile strength. All coveralls tested showed a positive CC-2 test. Tensile tests were run on the Scott tensilometer. The tensile strengths varied from a low of approximately 70 lbs. to a high of about 180 lbs. It was concluded that the erratic deterioration of impregnated clothing in storage is related to variables existing in the impregnation process. Tabulated results and a graph showing tensile strength vs. batch number are included.
Text. Research J. Oct. 1946

German Research

Dyeing and Finishing Methods

Observations on dyeing and finishing methods in Germany. (FIAT Final Report 644.) C. Norris Rabold. PB 16680, Dec. 19, 1945; 173 pp.; microfilm, $2.00—photostat, $12.00 (through *Bib. Sci. and Ind. Reports* 1, 1295 (June 7, 1946)).

Since much of the information presented came from the laboratories of I. G. Farbenindustrie, it may be considered the latest on application techniques. Plants were poorly laid out, with considerable hand labor in each operation. There were few indicating thermometers on drying machines, although bleaching and dyeing formulas were very exact as to times, temperatures, and concentrations. The dyeing industry is conscious of fast colors, a large part of the work being dyed with indanthrene, anthrosol, and napthol colors. Developed colors are more commonly used than direct colors. For shrinkage, some fabrics were loop-dried and short-framed, others were shrunk by overfeeding onto pin tenters, and some were set with urea or melamine resins or by a formaldehyde treatment. Tables, graphs, and diagrams are included.
Text. Research J. Oct. 1946

Dyeing Rayon

The dyeing of spun rayon and rayon filament yarn in mechanical apparatus in Germany. (FIAT Final Report 645.) Thomas R. Smith. PB 27524, Dec. 1945; 19 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* 2, 307 (July 26, 1946)).

Generally speaking, the machinery for dyeing packages, cheeses, and beams in pressure machines in Germany has not advanced as far as in the U. S., with one exception—where rayon cakes have been dyed in a new machine developed jointly by Dr. Diem at the I. G. Farben Rayon Plant in Rottweil and Obermaier and Company of Neustadt on the Haardt, near Mannheim. One new method of vat-dye application, known as the "Kuepensaeure," developed by I. G. for the dyeing of vat colors on rayon, both spun and filament, is given in detail in Appendix 2. Formulas are included.
Text. Research J. Oct. 1946

Dyeing Synthetic Fabrics

Some aspects of rayon and synthetic fabric dyeing and processing in Germany and Austria. (FIAT Final Report 556.) Glenn D. Jackson, Jr. PB 16673, Dec. 1945; 60 pp.; microfilm, $1.00—photostat—$4.00 (through *Bib. Sci. and Ind. Reports* 1, 1431 (June 14, 1946)).

German plant equipment is in many instances unique, clever, and well designed. The speed of these units is slower than would be acceptable under American operating economy, and labor employed is excessive. Dyeing equipment is particularly well designed, but their becks are too small for our larger production lots. A novel arrangement of pads, jigs, and *quetsche* in one plant is reported herein. No new developments were observed in acetate dyeing and since Perlon was relatively new, acetate-type dyes were still in use where small amounts of this fiber had been dyed. Appendices contain reports of the following textile dyeing and printing plants: Württembergische Kattun Manufactur at Heidenheim, Württemberg; Neue Augsburger Kattun Fabric at Augsburg, Bavaria, Germany; Bleicherei, Faberei, und Appretur Anstalt Uhingen A. G.; Gabriel Herose A. G., Konstanz, Germany; Baumwollindustrie Erlangen-Bamberg A. G.; and Calico- und Kunstleder-Werke. Also included are diagrams of an open-width desizing tank, glass-enclosed beck, cross section of porcelain beck rod, pad, jig, and *quetsch* range, and "vat acid" and "elektrofixier" range.
Text. Research J. Oct. 1946

Dyes and Intermediates

German dyestuffs and intermediates; sodium hydrosulphite, sodium sulphoxylate: Industries. (BIOS Final Report 271, Item 22.) P. C. Holmes. PB 22409, Feb. 1946; 22 pp.; microfilm, 50¢—photostat $2.00 (through *Bib. Sci. and Ind. Reports* 1, 1529 (June 28, 1946)).

Report describes the production at I. G., Höchst, Frankfort on the Main, of the following: pyranil, nitropyrene, amino pyrene, chloranil, and Sirius Light Blue. There

is a description of the azo-dye plant including vats, presses, ice plant and driers. Information was also received about the constitution of the metachrome dyes. Report also describes the production at the I. G. Farben plant at Leverkusen of zinc hydrosulfite, sodium hydrosulfite, and sulfoxylates (Rongalit). Flow sheets of the zinc hydrosulfite process are attached.

Text. Research J. Oct. 1946

New Dyes and Processes

The development of new dyes and color application processes in Germany and Italy during World War II. M. A. Dahlen. PB 31004, Oct. 1945; 462 pp.; microfilm, $10.00—photostat, $31.00 (through *Bib. Sci. and Ind. Reports* **2**, 313 (Aug. 2, 1946)).

This document forms part of the canceled report PB 2461, abstracted in the *Bibliography* **1**, p. 148. This account surveys the German (I. G. Farbenindustrie) and Italian (Montecatini) dye laboratories to determine the new dyes and intermediates and new color applications developed during the war years, with particular attention to developments adaptable to the production of military products. Although research in Germany and Italy was at a low ebb during the war, the investigators report over 100 new dyes. There are a general discussion of dye developments in the two countries and a total of 87 appendices each giving individual specifications for new dyes and color applications. For parts 1 and 2, see PB 31002 and 31003, respectively.

Text. Research J. Oct. 1946

Fiber Properties

Faserstoffe (Fibers). (Reichsluftfahrtministerium, Ringbuch der Luftfahrttechnik II C 18.) (Alsos Mission, Klotter Fille 11 B.) Kurt Riechers. PB 14584, Oct. 1938; 21 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 58 (July 5, 1946)).

This report is one of a series published by the German air ministry. The report covers the results of tests upon fibers and cloth woven of the fibers, to determine their suitability for use in aircraft. Mechanical and physical tests such as tensile strength, moisture absorption, etc., are described and test equipment is illustrated. The fibers were mainly of plant origin, such as cotton, kapok, hemp, linen, etc., but silk and synthetic and mineral fiber were also included. Tables, graphs, and photographs are included.

Text. Research J. Oct. 1946

I. G. Farben Publications

Publications at I. G. Farben laboratory building, Höchst. (FIAT Final Report 346.) Julian F. Smith. PB 22438, Oct. 1945; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 151 (July 12, 1946)).

This report lists 38 publications (1940–1944) which might prove interesting to the textile industry. It was recommended that the "Mitteilungen" of various textile schools be examined to locate any original material. Cards selected from a collection of I. G. Farben sample cards of military and raincoat fabrics and accompanying directions for dyeing or finishing are filed in Col. Steadman's office, together with a classified list. The classes are listed in the report.

Text. Research J. Oct. 1946

Knitted Fabrics

Circular knitting and its development in Germany since 1930; supplement. (For original report see PB 6347.) (FIAT Final Report 330.) P. H. Hanes, Jr., and C. L. Rosenquist. PB 23407, n.d.; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 1430 (June 14, 1946)).

This is a list of 56 samples of knitted materials made by the circular interlock knitting machines of Fouquet & Franz, of Rottenburg a.N., Germany, which are now available for inspection at the U. S. National Bureau of Standards. These were obtained during an inspection of this plant which is reported in PB 6347, Vol. 1, page, 459, of this *Bibliography*. Among the samples are interlock backing cloth, face plain, back plated with little lining loops (napped); vertical pearl striping; 2- and 3-color check effects; and block and stripe effect.

Text. Research J. Oct. 1946

Some aspects of the full fashioned and warp knitting industry in Germany; supplement. (For original report see PB 14523.) (FIAT Final Report 561, Supplement.) Max Winkler and Hans G. Fiedler. PB 23406, n.d.; 2 pp.; microfilm, 50¢—photostat $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 1431 (June 14, 1946)).

This is a list of samples obtained in an investigation of the full-fashioned and warp knitting industry in Germany, reported in PB 14523, Vol. 1, page 966, of this *Bibliography*. These samples are now available for inspection at the U. S. National Bureau of Standards. Included are samples of circular-knit underwear fabric, rayon underwear, rayon hose, heavy circular-knit hose, a runproof fabric made on circular spring needle machine, 2-way-stretch bathing suit fabric. Also included are a number of samples which are not knitted, including 15 samples of fur imitation, 2 samples of fine corduroy, and fabric gloves with leather palms. These samples were obtained from Heinzelmann & Co., Reutlingen, Württemberg; Vereinigte Strumpffabriken, Kulmbach, Bavaria; Minthorst & Schulte, Krefeld; Alber-Bitzer, Tailfingen, Württemberg; R. Vollmoeller, Inc., Stuttgart-Vaihingen; and Gebr. Haaga, Stuttgart.

Text. Research J. Oct. 1946

Finishing Rayon

German methods for finishing rayon fabrics. (QM Textile Series, Report 21.) Glenn D. Jackson. PB 27732, May 1946; 73 pp.; microfilm, $2.00—photostat, $5.00 (through *Bib. Sci. and Ind. Reports* **2**, 307 (July 26, 1946)).

This report is one of a series pre-

pared by a "Textile Finishing Team" which was organized to explore German developments in the field of textile auxiliaries and finishing agents. In it the following subjects are treated: (1) some aspects of rayon and synthetic fabric dyeing and processing in Germany and Austria; (2) producing durable embossing on rayons and a machine for coloring embossed fabrics; and (3) a German finish of spun rayon fabrics combining water-repellency, crease-resistance, and low residual shrinkage. Reports, documents, and interviews obtained by the Textile Finishing Team from which this report was prepared are appended (pp. 18–70). These include sketches and photographs of equipment, formulas, translation of a paper on "vat acid" process, letter by I. G. Farben on dyeing Astrazon colors, and reports on the following plants: Württembergische Kattun Manufaktur at Heidenheim; Neue Augsburger Kattun Fabrik at Augsburg; Gabriel Herose A. G., Konstanz; Baumwollindustrie Erlangen-Bamberg; Bleicherei, Färberei, und Appretur Anstalt Uhingen A. G., and Calico- und Kunstleder-Werke at Göppingen, Württemberg. The first four plant reports may also be found in PB 27730. Dyeing equipment was found to be particularly well designed but their becks were too small for our larger production lots. A novel arrangement of pads, jigs, and *quetsche* in one plant is reported. Newer dyes of I. G. Farben had found little use in the trade owing to the war. Since Perlon was relatively new, acetate dyes were still in use.

Text. Research J. Oct. 1946

Rayon Manufacture*

The viscose continuous and rayon staple fibre plants of the British, American, and French occupation zones of Germany. (BIOS Final Report 290, Items 22, 31.) L. Hemsley and others. PB 20093, Jan. 1946; 342 pp.; microfilm, $3.50—photostat, $23.00 (through *Bib. Sci. and Ind. Reports* **2**, 57 (July 5, 1946)).

The team which visited these factories went with the idea of assessing the value of any suitable plant likely to be seized as reparation in accordance with the Potsdam Agreement. The report is divided into 4 parts. Part 1, a covering report of the trip, describes briefly the outstanding features of the following firms: Karl Zang, Krefeld; Rheinische Kunstseide Fab., Ürdingen; Barmag Maschinen Fab., Lennep; Kampf & Spindler-Hilden, Düsseldorf; Glanzstoff Courtaulds, Köln; Rheinische Zellwolle, Siegburg; Kuehlne, Kopp & Kausch, Frankenthal; Hereaus Hannau, Frankfort on the Main; Vereinigte Glanzstoff Fab., Obernberg; Vereinigte Glanzstoff Fab., Kelsterbach; Gustav Eirich, Hardheim; I. G. F. Ludwigshaven, Oppau; Deutsche Waffen & Mun. Fab., Karlsruhe; Fritz Müller-Esslingen, Stuttgart; Zellwolle Lehrspinnerei, Denkendorf; Werner Pfleiderer Feuerbach, Stuttgart; I. G. F. Bobbingen, Augsburg; Süddeutsche Zellwolle A. G., Kehlheim; Sartorius, Göttingen; and Spinnfaser A. G., Kassel. Part 2 of the report presents in tabular form the machinery earmarked as suitable for reparations from Germany giving the estimated replacement value in pounds sterling. Part 3 presents similar data but includes machinery suggested as suitable for either reparations or prototypes from Germany. Part 4 presents a detailed technical report on every target visited. This part begins with a brief description of the latest shredding and mixing devices used in the viscose spinning industry in Germany, followed by a discussion of each target which includes information on outstanding features of the plant, condition of the factory, capacity, production data, drawings of machines, flow sheets and sketches of processes as carried on in the plant.

Text. Research J. Oct. 1946

* This report contains comparable information to that contained in PB 377, "Continuous and Staple Fiber Plants in Germany." Both of these reports were preliminary surveys and most of the information will be found in PB 7416, *Synthetic Fiber Developments in Germany*, recently issued by Textile Research Institute, Inc., 1,060 pages with chart supplement, price, $10.00.—*Editor*

Rayon Weaving

Rayon weaving and throwing, Kampf and Spindler, Hilden near Düsseldorf. (FIAT Final Report 663.) Ernest C. Geier. O.P.B. Report PB 8273, 1945; 3 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 961 (May 3, 1946)).

This is one of the few concerns in Germany which is fully integrated. Kampf and Spindler spin their own viscose yarn, prepare and throw (twist) it into various descriptions, and do their own weaving. The dyeing and finishing are done outside. The integration from spinning to woven fabric makes possible a few short cuts, which should reduce costs, offset by obsolete operating methods.

Text. Research J. Oct. 1946

Processing of Spun Rayon Yarn

Processing of spun rayon yarn in Germany. (BIOS Final Report 177, Item 22.) P. Chapuis. PB 19679, Jan. 1946; 17 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **1**, 1430 (June 14, 1946)).

This report consists of brief descriptions of the following targets: Württembergische Baumwollspinnerei und Weberei, Brühl nr. Esslingen; Christian Deirig AG, Augsburg; Augsburger Buntweberei Riedinger, Augsburg; Spinnerei und Weberei Zell Shonau, Shonau near Zell; Spinnerei und Weberei, Offenburg; Kollnauer Baumwollspinnerei und Weberei, Kollnau nr. Waldkirch; Buntweberei Sulz GmbH, Sulz (Neckar); Zellwolle Lehrspinnerei, Denkendorf. The Zellwolle Lehrspinnerei has made studies and tests of the effect of humidification, temperature, picking, carding, and spinning of rayon yarn. These are reported briefly herein. Sketches and photography of machinery are included in the report.

Text. Research J. Oct. 1946

Research Institute Documents

Report on German Research Institute for the Textile Industry at

München-Gladbach-Rheydt. (Supplement, documents in German; 35 mm. microfilm. For original report see PB 27451.) H. F. Schiefer and R. T. Kropf. PB 27452, n.d.; 222 pp.; microfilm, $5.00—photostat, $22.25 (through *Bib. Sci. and Ind. Reports* **2**, 58 (July 5, 1946)).

This microfilm contains the copies of the original German documents noted and summarized in the English report by Herbert F. Schiefer and Richard T. Kropf on German Research Institute for the Textile Industry at München-Gladbach-Rheydt (PB 27451).

Text. Research J. Oct. 1946

Research Institute Reports

Report on German Research Institute for the Textile Industry at München-Gladbach-Rheydt. (For supplement, on microfilm, containing documents in German, see PB 27452.) H. F. Schiefer and R. T. Kropf. PB 27451, n.d.; 5 pp.; microfilm, $1.00—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 58 (July 5, 1946)).

This report includes summaries in English of important publications from the Textile Institute at München-Gladbach-Rheydt. The publications include doctoral dissertations and should be of particular interest to textile schools in this country. The publications are: (1) Retention of the cellulose molecular structure in staple fiber manufacture, by Dr. Otto Mecheels (Director of the School of Technology at Aachen) and Gerhard Dierkes, 1937, 34 pp.; (2) Research on alkali ageing or ripening of wood cellulose, by Otto Mecheels and Hubert Werning, 1938, 32 pp.; (3) Effects of chemicals on wool and quantitative methods for the determination of damage to wool, by Otto Mecheels and Erich Feller, 1939, 56 pp.; (4) Technical and scientific work for the clothing industry, 1940, 62 pp. (this series contains articles on (*a*) shrinkproofing of clothing, by P. Hoff; (*b*) selvedges for fabrics, by O. Mecheels; (*c*) a study of assembly-line methods in the manufacture of men's outerwear clothing, by E. Donner; (*d*) thermal insulation of clothing, by O. Mecheels; (*e*) cutting uniform coats from full-width fabrics vs. half width of doubled fabric, by Schleypen; (*f*) a cost study in steam pressing plants, by E. Donner; (*g*) lighting, heating, and ventilating in clothing factories); (5) Technological investigations and time studies for the production of army overcoats by E. Donner, 1941, 84 pp.; (6) Fish-protein in nutrition and clothing—Part I, by P. P. Hiltner, on the ocean as a source of raw material, Part II, by O. Mecheels, on fish-protein animal-like fiber, 1939, 27 pp.; (7) Fish-protein animal-like staple fiber "Wikilan," by O. Mecheels and K. A. Essig, 1940, 58 pp.; (8) Textile finishing, by O. Mecheels, 1940, 380 pp. (a textbook on finishing procedures, testing methods, and instructions for experimental work); (9) Testing instruments for the textile industry, by W. Oeser, 1940, 150 pp.; (10) Results of scientific investigations, by Otto Mecheels, 8 pp. (manuscript). 11 abstracts covering the following subjects: (*a*) mercerization of cotton, (*b*) measurement of softness, (*c*) water-repellent finishes, (*d*) mothproofing of wool with Eulan, (*e*) bleaching, (*f*) measurement of resistance to wear, (*g*) textile finishing agents, (*h*) fibers from fish-protein, (*i*) effect of finishes on durability of textiles, (*k*) functional studies of clothing, (*l*) work clothing. These publications, including the manuscript point, written in German, have been deposited in the Library of the National Bureau of Standards, Washington, D.C., where they can be consulted, and are reproduced in full in PB 27452.

Text. Research J. Oct. 1946

Research in Synthetic Fibers

Arbeitsring für synthetische Faserstoffe—Dipl.-Ing. Dr. Dörr. (Reports on activities of a research group working on the development of new synthetic textile fibers.) (R F R 214.) Reichsforschungsrat, Germany. O.P.B. Report PB 12767, 1942–44; 403 pp.; microfilm, $4.50—photostat, $28.00 (through *Bib. Sci. and Ind. Reports* **1**, 962 (May 3, 1946)).

Text. Research J. Oct. 1946

Screen Printing

Screen printing. (QM Textiles Series, Report 5.) M. L. Crossley and Francis L. Richardson. PB 23638, n.d.; 17 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 57 (July 5, 1946)).

This document contains two reports on the subject of screen printing: One prepared by Dr. M. L. Crossley, based on his observations and discussions with Sergeant H. H. Hiett and Mr. Klimsch, about the screen printing process used by Klimsch and Company, Frankfort on the Main; and an article prepared by Francis L. Richardson, based primarily upon interviews with Franz Nestleberger, textile printing engineer, at the Höchst plant of I. G. Farben. In the screen printing process used by Klimsch and Company the screen is fine copper filter cloth similar to that used to filter gasoline. It is coated with a water solution containing polyvinyl chloride and ammonium bichromate. It is dried at about 35°C. The design to be impressed on the sensitized film is placed in contact with it and exposed to light for a short time. The light causes the bichromate to oxidize the polyvinyl chloride to an insoluble film, the unexposed portion of the film dissolving off in water and leaving the design on the screen. This printing screen is inked and used to print the design. Excess printing ink can be removed by washing with water or benzine, depending on the nature of the printing ink used. Finally, when no further prints of the design are needed, the design is removed from the screen with potassium permanganate and sulfuric acid, the screen washed thoroughly with water and dried. It is then ready to be recoated for a new design. The article by Francis L. Richardson states that the new process for producing printing screens encountered at the Höchst plant of I. G. Farben makes practical the production of screens with considerably finer execution

of detail than was previously possible. The screens produced in this manner are much more durable and less susceptible to chemical action and damage. This new method of producing printing screens utilizes a new type of lacquer, "Screen Lacquer N," made light-sensitive by the addition of bichromate, using "hardener NA," "screen blue N," and "covering lacquer N." "Screen lacquer N" is saponified polyvinyl acetate, obtainable from chemical manufacturers. "Hardener NA" is a mixture of 3 parts of formaldehyde and one part of butylaldehyde, 25% xytol and 25% butanol. Originally a phenol resin was used, but the beetle syrup was found to give better results.

Text. Research J. Oct. 1946

Sewing Thread Industry

The German sewing thread industry. (FIAT Final Report 710.) Herbert F. Schiefer and Richard T. Kropf. PB 27125, Jan. 1946; 37 pp.; microfilm, $1.00—photostat, $3.00 (through *Bib. Sci. and Ind. Reports* **2**, 307 (July 26, 1946)).

This report consolidates reports made by the authors and issued as FIAT final reports, mimeographed for limited distribution. The first section is a summary of the industry as a whole (FFR–315). The German sewing thread industry produced a total of approximately 8,000,000 kilograms of thread products per year, amounting to an annual sales of approximately 100,000,000 marks. During the war the production and sales were approximately 150% of normal. Normally the products consisted of sewing threads, darning threads, and art needle threads produced from cotton, linen, silk, and rayon. During the war cotton was cut off and threads were made primarily from spun rayon and from high-strength rayon as well as smaller quantities of linen and silk. The production methods and equipment used throughout the industry are quite conventional, and follow the usual designs. The distribution and sales of the industry are handled primarily by sales syndicates. It is estimated that these syndicates handle 90% of the business. The German thread industry has not sponsored fundamental or applied research. When such work has been required, it has been referred to outside organizations. Some research has been done, however, and outstanding research has been presented briefly in the second section (FFR-307). Sections 3–9 cover the following manufacturers: Albert Aug. Knapp at Pfullingen (FFR-304); A. G. Mez, Freiburg (FFR-305); Zwirnerei Ackermann, A. G., Sontheim (FFR-308); A. Schradin & Co., Reutlingen (FFR-309); Amann & Söhne, Bönnigheim (FFR-310); Zwirnerei and Nähfadenfabrik Göggingen, A. G., Göggingen (FFR-311); and Gütermann A. G., Gutach (FFR-312). Within the sections are SKR numbers referring to Schiefer-Kropf Reports, listed in full in Appendix III. Appendix I consists of notes on personnel, Appendix II is a government regulation, and Appendix IV a bibliography of available documents and list of samples.

Text. Research J. Oct. 1946

Exposure Foam Suit

The German aviation exposure foam suit. (Naval Tech. Mission in Europe, Tech. Report 495–45.) A. H. Andrews, Jr. PB 22948, Sept. 1945; 10 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 57 (July 5, 1946)).

An exposure foam suit developed for use by the German Air Force is described in this report. Tests conducted by the Germans indicated that it is effective in prolonging the life expectancy of personnel immersed in extremely cold water. The suit is made of medium-weight quilted material and includes a jacket, trousers, mittens and foot pads. Upon contact with the water, the chemical powder contained in each section of the quilted suit reacts with the water and releases a carbon dioxide foam. This gas forms a protective layer which reduces the rate of loss of body heat and thereby affords protection against extremely cold water. The description of these suits and of experiments in their use and formulas of gas-producing chemical are given. Graphs of data are included.

Text. Research J. Oct. 1946

The German emergency flying suit. (Naval Tech. Mission in Europe. Tech. Report 174–45.) J. M. Jayne. PB 22802, Aug. 1945; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 58 (July 5, 1946)).

The suit is made of a medium-weight quilted material, and the complete suit consists of: 1 jacket, 1 pair of trousers, 1 pair of mittens, and 1 pair of foot pads. Upon contact with water, the chemical powder contained in each square of the quilted suit reacts with the water and releases a gas believed to be CO_2. This gas forms a protective layer that tests by the Germans have indicated as being successful in retaining the body heat of the wearer and thereby affording protection against extremely cold water. The tests indicated that the suit was effective for periods up to 8 hrs.

Text. Research J. Oct. 1946

Protective Suit

Report on construction of a special protective garment to prevent cooling off in water. Herbert F. Schiefer and Richard T. Kropf. PB 23399, n.d.; 10 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 1431 (June 14, 1946)).

This report discusses the development at the textile laboratory at München-Gladbach of a special protective garment which was designed to prevent the excessive loss of body heat by men who had fallen into cold sea water. When fire-extinguishing foam proved unsatisfactory, a foam powder was developed which would generate foam when it came into contact with sea water. This powder was rubbed into the wool-like pile of the middle layer of a 3-layer garment and the foam was generated when the sea water penetrated the outer layer of the garment. It was claimed that this garment effectively retained the body heat of a person for 2 or 3 hrs. in cold sea water. Chemical com-

pound of foam powder for the protective garment for use in the North Atlantic and North Sea is given. Graphs showing the foam production and drawings of the garments illustrate the report. Information in this report was obtained from Dr. Otto Mecheels at the Schloss Hohenstein.

Text. Research J. Oct. 1946

Test Methods

Evaluating serviceability of textile fibers in Germany. H. F. Schiefer and R. T. Kropf. O.P.B. Report PB 12963, n.d.; 44 pp.; microfilm, 50¢—photostat, $3.00 (through *Bib. Sci. and Ind. Reports* **1**, 964 (May 3, 1946)).

This report is based on information contained in FIAT Reports 173, 307, and 313. From the textile research in Germany it may be concluded that the serviceability of a textile product cannot be predicted from the results of an abrasion test alone. The Germans probably have made more progress than any other country in actually combining the results of tests of as many as 9 or 10 different properties into a single numerical wear index. Dozens of different instruments and methods have been devised to evaluate the various properties of fibers, yarns, and fabrics. Since the economic conditions in Germany and the kind and supply of fibers were different from those in the United States, the numerical values presented here probably have little meaning as such and should be regarded as illustrative only. This report discusses research on knitted fabrics (men's socks) by Schachenmayr, Man & Cie., on sewing thread by Guetermann, A. G., and on comparison of sewing thread by Reutlingen Research Institute. Tables showing approximate results of service, calculation of wear index, laboratory wear indices, and index numbers and graphs showing laboratory index and relative percentages are included. There is also a discussion of testing instruments including fiber flexing, yarn flexing, fabric flexing, yarn abrasion, Jansen yarn tester, Mecheels' yarn tester, Müller fabric tester, Schopper abrasion tester, Repenning abrasion tester, Repenning impact and abrasion tester, Krais single-fiber tester, Schopper single-fiber tester and Schopper yarn tester. The discussion of these instruments includes a description, operating procedure, diagrams, and several photographs.

Text. Research J. Oct. 1946

Textile Printing

The textile printing industry in Germany. (QM Textile Series, Report 20.) Elliot Broadbent and others. PB 27730, May 1946; 67 pp.; microfilm, $2.00—photostat, $5.00 (through *Bib. Sci. and Ind. Reports* **2**, 306 (July 26, 1946)).

Text. Research J. Oct. 1946

Textile Education

Textile education in Germany. William D. Fales and others. PB 3892, 1945; 24 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 150 (July 12, 1946)).

The primary fields of interest for the investigation covered by this report were a study of the types of textile schools in Germany, their organization and administration, their curricula, teaching methods, and research programs. The report consists of a general discussion of the German textile schools, and a rather complete description of the Staatl. Technikum für Textilindustrie at Reutlingen, Württemberg, an outstanding textile educational institution and the only school of the higher level that was not at least partially destroyed during the war. Contents include description of buildings and equipment at Technikum; testing laboratories; personnel; entrance requirements and duration of training; school fees; and types of courses offered.

Text. Research J. Oct. 1946

Textile Scientists

Research personality in textiles of Germany. (FIAT Final Report 314.) Herbert F. Schiefer and Richard T. Kropf. PB 22423, Oct. 1945; 6 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 150 (July 12, 1946)).

This report presents briefly the outstanding personalities in the textile industry in Germany, namely: Dr. Ing. Bernhard Bisinger, Prof. Dr. Ing. Egon Elöd, Prof. Dr. Ing. Otto Johannsen, Dr. Prof. Dr. Ing. Otto Mecheels, Dipl.-Ing. Wilhelm Meyer, Dr. Ing. Curt Mierisch, Dr. Ing. W. Oeser, Prof. Dr. Hermann Rath, Dr. N. Reinfeld, Dr. Carl Rösch, Prof. Dr. Hermann Staudinger, Frau Dr. M. Staudinger, Dr. Stock, Dipl.-Ing. Albert Von Ostermann, Prof. Dr. Ing. F. Walz, and Dr. H. Zahn.

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Textile Testing

Research on textile testing, instruments, methods, standards, and on properties of textile fibers in Germany. (FIAT Final Report 173.) Herbert F. Schiefer and Richard T. Kropf. PB 22414, Oct. 1945; 9 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 150 (July 12, 1946)).

As the result of the tremendous development of the staple rayon industry, the Schopper single fiber tester and the Frenzel-Hahn continuous yarn tester are used extensively in Germany. One of the outstanding developments in the field of textile instrumentation was the magnetic weighing beam used in connection with the Frenzel-Hahn yarn tester to measure the variation in tension of the yarn as it is run through the machine at a given elongation. It was also used to measure the tension of the yarn as it is run through the machine at a given elongation. It was also used to measure the tension in roving during the drafting process. The method of determining an index of wearability of knitted fabrics based on a weighted combination of the results of 10 different physical tests, including dry and wet breaking strength, dry and wet yarn abrasion-resistance, and flexing in addition to abrasion-resistance of the fabric, is considered. The technique developed for partial acetyla-

tion of a fiber, dissolving the acetylated layer to permit a study of the swelling and density of the fiber layer by layer, seems unique and useful. Some of the material in this report is summarized in PB 12963, abstracted in Vol. 1, p. 964, of this *Bibliography*.

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Textile Testing

Textile testing in Germany. (FIAT Final Report 466.) Lyman Fourt and others. O.P.B. Report PB 3883, 1945; 21 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **1**, 961 (May 3, 1946)).

This report presents a general picture of textile testing in Germany, with emphasis on the effort to measure the properties of fibers, yarns, and fabrics which would lead to greatest service value in actual use. It recommends that American laboratories and instrument makers should build and make available the following types of testing machines for wear testing: (1) a round tester, based on the Schopper or Bleyle tester, the results of which can be evaluated by bursting strength; (2) a flat type, like the Müller, for differential testing of warp and filling; (3) a localized abrasion tester; and (4) a flexing endurance tester, capable of performing the test with either wet or dry fabric, with the possibility of varying the tension in relation to the breaking strength of the cloth. It also recommends that physiological aspects of clothing, such as fabric warmth, the effect of fabric surface structure on the sensation of warmth, the moisture content of clothing under varying conditions of climate and activity, the effect of wind in relation to clothing layers and fabric porosity, and the like, should be studied in the United States, in relation to the various fibers used in clothing, especially cotton, wool, viscose, acetate, and nylon. A third recommendation is that a carefully planned program of service testing, in correlation with laboratory testing, should be carried on in the United States. Sources of information are listed.

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Viscose Research

Viscose research and textile testing at Vereinigte Glanzstoff A. G., Research Laboratory, Wuppertal-Elberfeld. (FIAT Final Report 326.) Julian F. Smith. PB 22429, Oct. 1945; 3 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 221 (July 19, 1946)).

Research at Elberfeld was mainly on wool-like and cotton-like varieties of *Zellwolle*. The formaldehyde treatment was investigated. New testing machines and designs include a yarn-to-yarn abrasion tester, 2 emery rod abrasion testers, and a thermal insulation tester for hollow fiber fabrics. A bibliography is included.

Text. Research J. Oct. 1946

Viscose Staple

Viscose staple fiber at Sachsische Zellwolle, A. G., Plauen, Germany. (FIAT Final Report 135.) F. Stanley Brown. O.P.B. Report PB 14454, 1945; 3 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 961 (May 3, 1946)).

Brief report on a self-contained company with a fairly large plant which has a capacity of 1,200 tons of viscose-staple fiber per mo.

Text. Research J. Oct. 1946

Warp Sizing

German developments in warp sizing. (QM Textile Series, Report 2.) Joseph Meierhans and others. PB 23637, Mar. 1946; 30 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 150 (July 12, 1946)).

This report contains information on German developments in warp sizing collected by the "Textile Team" sent to Germany by the Office of The Quartermaster General in the summer of 1945. The contents include: (1) German developments in sizing of spun rayon and filament rayon warps; (2) "Feikes" system of warp sizing, including the formula for this process and tables showing the results of tests of different sizes; (3) "Sizing with Tylose," a brief article on Tylose warp sizes which are a series of water-soluble compounds sold by Kalle & Company, Wiesbaden-Biebrich; formulas, methods of sizing and photographs of sized and unsized rayon and sizing machines are included; and (4) "Manufacture of Tyloses and other water-soluble cellulose derivatives," which is an extract from a report on German plastics practice by Dr. John DeBell, Mr. Walter E. Gloor, and Mr. William C. Goggin, who were sent as observers into Germany to investigate technical developments in plastics. For the latter report, see PB 12467.

Text. Research J. Oct. 1946

Wash-Fastness

Laundering properties of fabrics, Grosswäscherei Raatz, 1 Neundorferstr., Berlin-Spandau. (FIAT Final Report 344.) Julian F. Smith. PB 21833, Oct. 1945; 2 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 1431 (June 14, 1946)).

This report is the final compilation of the interrogation on Sept. 4, 1945, of Dr. O. Viertel, former assistant of Dr. H. Sommer at the Staatliches Materialprüfungsamt, Berlin. Dr. Viertel has investigated the theory and practice of laundering fabrics without damage, applications of soapless detergents, laundry-fastness of special finishes, and related topics. Nearly all of Dr. Viertel's work has been published, and this is merely a documentation report. Three books, 13 articles, a manuscript, and a reprint, and a reprint of a published paper are listed.

Text. Research J. Oct. 1946

German Woolen Industry

Thomas Scheuffelen, Ebersbach, with comments on the German woolen industry. (FIAT Final Report 544.) Franklin W. Dorman. O.P.B. Report PB 13811, 1945; 4 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **1**, 961 (May 3, 1946)).

This report gives a detailed account of a visit to this mill to observe operations and equipment.

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